Impact of Global Warming Scenario on Business in India

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ABSTRACT

In this study, Author found some of the findings and objectives related with economical responsibility of global warming. Global warming may be responsible in part for some trends in natural disasters such as extreme weather. Based on future projections of climate change, the IPCC report makes a number of predictions. It is predicted that over most land areas, the frequency of warm spells/heat waves will very likely increase. It is likely that: Increased areas will be affected by drought, There will be increased intense tropical cyclone activity, There will be increased incidences of extreme high sea level (excluding tsunamis). Storm strength leading to extreme weather is increasing, such as the power dissipation index of hurricane intensity. Kerry Emanuel writes that hurricane power dissipation is highly correlated with temperature, reflecting global warming. However, a further study by Emanuel using current model output concluded that the increase in power dissipation in recent decades cannot be completely attributed to global warming. Hurricane modeling has produced similar results, finding that hurricanes, simulated under warmer, high-CO2 conditions, are more intense, however, hurricane frequency will be reduced. Worldwide, the proportion of hurricanes reaching categories 4 or 5 – with wind speeds above 56 meters per second – has risen from 20% in the 1970s to 35% in the 1990s. Precipitation hitting the US from hurricanes has increased by 7% over the twentieth century. The extent to which this is due to global warming as opposed to the Atlantic Multi-decadal Oscillation is unclear. Some studies have found that the increase in sea surface temperature may be offset by an increase in wind shear, leading to little or no change in hurricane activity. Hoyos et al. (2006) have linked the increasing trend in number of category 4 and 5 hurricanes for the period 1970-2004 directly to the trend in sea surface temperatures. Increases in catastrophes resulting from extreme weather are mainly caused by increasing population densities, and anticipated future increases are similarly dominated by societal change rather than climate change. The World Meteorological Organization explains that "though there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record to date, no firm conclusion can be made on this point. They also clarified that "no individual tropical cyclone can be directly attributed to climate change. Thomas Knutson and Robert E. Tuleya of NOAA stated in 2004 that warming induced by greenhouse gas may lead to increasing occurrence of highly destructive category-5 storms. In 2008, Knutson et al. found that Atlantic hurricane and tropical storm frequencies could reduce under future greenhouse-gas-induced warming.[26] Vecchi and Soden find that wind shear, the increase of which acts to inhibit tropical

cyclones, also changes in model-projections of global warming. There are projected increases of wind shear in the tropical Atlantic and East Pacific associated with the deceleration of the Walker circulation, as well as decreases of wind shear in the western and central Pacific. The study does not make claims about the net effect on Atlantic and East Pacific hurricanes of the warming and moistening atmospheres, and the model-projected increases in Atlantic wind shear. A substantially higher risk of extreme weather does not necessarily mean a noticeably greater risk of slightly-above-average weather. However, the evidence is clear that severe weather and moderate rainfall are also increasing. Increases in temperature are expected to produce more intense convection over land and a higher frequency of the most severe storms

Key wordfs: *Global warming- climate change-tropical cyclone activity- attributed-increasing- substantially*

INTRODUCTION

Global warming in one of the hot issue, how its effect in the global scenario especially in business and economy under this how the countries react , how the company react what kind of solution its need. The effects of global warming and climate changes are of concern both for the environment and human life. Evidence of observed climate change includes the instrumental temperature record, rising sea levels, and decreased snow cover in the Northern Hemisphere. According to the IPCC Fourth Assessment Report, most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in human greenhouse gas concentrations". It is predicted that future climate changes will include further global warming (i.e., an upward trend in global mean temperature), sea level rise, and a probable increase in the frequency of some extreme weather events. Ecosystems are seen as being particularly vulnerable to climate change. Human systems are seen as being variable in their capacity to adapt to future climate change. To reduce the risk of large changes in future climate, many countries have implemented policies designed to reduce their emissions of greenhouse gases. The impact of future climate change on human systems will likely be unevenly distributed. Africa is probably the most vulnerable continent to future climate change. Developing countries are probably more vulnerable to climate change than developed countries. With warming of 1-2°C above 1990-2000 levels, it is likely that key negative impacts would be experienced in some regions, e.g., Arctic nations and small islands. In other regions, some population groups would be threatened by this level of warming, e.g., high-altitude communities and coastal-zone communities with significant levels of poverty. Above 2-3°C warming, it is likely that most countries would experience net negative impacts.The total economic impacts of climate change are highly uncertain. Typical estimates of climate change impacts are of a change in gross world product of plus or minus a few percent. Small changes in gross world product could be associated with relatively large changes in national economies.

Glacier retreat and disappearance

In historic times, glaciers grew during a cool period from about 1550 to 1850 known as the Little Ice Age. Subsequently, until about 1940, glaciers around the world retreated as the climate

warmed. Glacier retreat declined and reversed in many cases from 1950 to 1980 as a slight global cooling occurred. Since 1980, glacier retreat has become increasingly rapid and ubiquitous, and has threatened the existence of many of the glaciers of the world. This process has increased markedly since 1995. Excluding the ice caps and ice sheets of the Arctic and Antarctic, the total surface area of glaciers worldwide has decreased by 50% since the end of the 19th century. Currently glacier retreat rates and mass balance losses have been increasing in the Andes, Alps, Pyrenees, Himalayas, Rocky Mountains and North Cascades.

The loss of glaciers not only directly causes landslides, flash floods and glacial lake overflow, but also increases annual variation in water flows in rivers. Glacier runoff declines in the summer as glaciers decrease in size; this decline is already observable in several regions. Glaciers retain water on mountains in high precipitation years, since the snow cover accumulating on glaciers protects the ice from melting. In warmer and drier years, glaciers offset the lower precipitation amounts with a higher melt-water input.

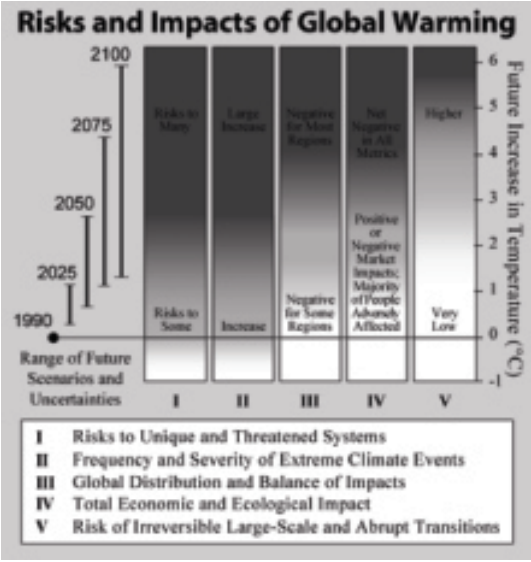
Of particular importance are the Hindu Kush and Himalayan glacial melts that comprise the principal dry-season water source of many of the major rivers of the Central, South, East and Southeast Asian mainland. Increased melting would cause greater flow for several decades, after which "some areas of the most populated regions on Earth are likely to 'run out of water'" as source glaciers are depleted The Tibetan Plateau contains the world's third-largest store of ice. Temperatures there are rising four times faster than in the rest of China, and glacial retreat is at a high speed compared to elsewhere in the world. According to a UN climate report, the Himalayan glaciers that are the sources of Asia's biggest rivers—Ganges, Indus, Brahmaputra, Yangtze, Mekong, Salween and Yellow—could disappear by 2035 as temperatures rise. Approximately 2.4 billion people live in the drainage basin of the Himalayan Rivers. India, China, Pakistan, Bangladesh, Nepal and Myanmar could experience floods followed by droughts in coming decades. In India alone, the Ganges provides water for drinking and farming for more than 500 million people. It has to be acknowledged, however, that increased seasonal runoff of Himalayan glaciers led to increased agricultural production in northern India throughout the 20th century.

The recession of mountain glaciers, notably in Western North America, Franz-Josef Land, Asia, the Alps, the Pyrenees, Indonesia and Africa, and tropical and sub-tropical regions of South America, has been used to provide qualitative support to the rise in global temperatures since the late 19th century. Many glaciers are being lost to melting further raising concerns about future local water resources in these glaciated areas. In Western North America the 47 North Cascade glaciers observed all are retreating. Despite their proximity and importance to human populations, the mountain and valley glaciers of temperate latitudes amount to a small fraction of glacial ice on the earth. About 99% is in the great ice sheets of polar and subpolar Antarctica and Greenland. These continuous continental-scale ice sheets, 3 kilometres (1.9 mi) or more in thickness, cap the polar and subpolar land masses. Like rivers flowing from an enormous lake, numerous outlet glaciers transport ice from the margins of the ice sheet to the ocean.

Glacier retreat has been observed in these outlet glaciers, resulting in an increase of the ice flow rate. In Greenland the period since the year 2000 has brought retreat to several very large

glaciers that had long been stable. Three glaciers that have been researched, Helheim, Jakobshavn Isbræ and Kangerdlugssuaq Glaciers, jointly drain more than 16% of the Greenland Ice Sheet. Satellite images and aerial photographs from the 1950s and 1970s show that the front of the glacier had remained in the same place for decades. But in 2001 it began retreating rapidly, retreating 7.2 km (4.5 mi) between 2001 and 2005. It has also accelerated from 20 m (66 ft)/day to 32 m (100 ft)/day. Jakobshavn Isbræ in western Greenland had been moving at speeds of over 24 m (79 ft)/day with a stable terminus since at least 1950. The glacier's ice tongue began to break apart in 2000, leading to almost complete disintegration in 2003, while the retreat rate doubled to over 30 m (98 ft)/day

Graph-1



Source: Compiled from internet Wikipedia-2009

Graphical description of risks and impacts from global warming from the Third Assessment Report of the Intergovernmental Panel on Climate Change. Later revisions to this work suggest significantly increased risks.

Physical impacts

Effects on weather

Increasing temperature is likely to lead to increasing precipitation but the effects on storms are less clear. Extra - tropical storms partly depend on the temperature gradient, which is predicted to weaken in the northern hemisphere as the polar region warms more than the rest of the hemisphere.

Global warming may be responsible in part for some trends in natural disasters such as extreme weather. Based on future projections of climate change, the IPCC report makes a number of predictions. It is predicted that over most land areas, the frequency of warm spells/heat waves will very likely increase. It is likely that:

1. Increased areas will be affected by drought

2. There will be increased intense tropical cyclone activity

3. There will be increased incidences of extreme high sea level (excluding tsunamis)

Storm strength leading to extreme weather is increasing, such as the power dissipation index of hurricane intensity. Kerry Emanuel writes that hurricane power dissipation is highly correlated with temperature, reflecting global warming. However, a further study by Emanuel using current model output concluded that the increase in power dissipation in recent decades cannot be completely attributed to global warming. Hurricane modeling has produced similar results, finding that hurricanes, simulated under warmer, high-CO2 conditions, are more intense, however, hurricane frequency will be reduced. Worldwide, the proportion of hurricanes reaching categories 4 or 5 – with wind speeds above 56 meters per second – has risen from 20% in the 1970s to

35% in the 1990s. Precipitation hitting the US from hurricanes has increased by 7% over the twentieth century. The extent to which this is due to global warming as opposed to the Atlantic Multi-decadal Oscillation is unclear. Some studies have found that the increase in sea surface temperature may be offset by an increase in wind shear, leading to little or no change in hurricane activity. Hoyos et al. (2006) have linked the increasing trend in number of category 4 and 5 hurricanes for the period 1970-2004 directly to the trend in sea surface temperatures. Increases in catastrophes resulting from extreme weather are mainly caused by increasing population densities, and anticipated future increases are similarly dominated by societal change rather than climate change. The World Meteorological Organization explains that "though there is evidence both for and against the existence of a detectable anthropogenic signal in the tropical cyclone climate record to date, no firm conclusion can be made on this point. They also clarified that "no individual tropical cyclone can be directly attributed to climate change.

Thomas Knutson and Robert E. Tuleya of NOAA stated in 2004 that warming induced by greenhouse gas may lead to increasing occurrence of highly destructive category-5 storms. In 2008, Knutson et al. found that Atlantic hurricane and tropical storm frequencies could reduce under future greenhouse-gas-induced warming.[26] Vecchi and Soden find that wind shear, the increase of which acts to inhibit tropical cyclones, also changes in model-projections of global warming. There are projected increases of wind shear in the tropical Atlantic and East Pacific associated with the deceleration of the Walker circulation, as well as decreases of wind shear in the western and central Pacific. The study does not make claims about the net effect on Atlantic and East Pacific hurricanes of the warming and moistening atmospheres, and the model-projected increases in Atlantic wind shear.

A substantially higher risk of extreme weather does not necessarily mean a noticeably greater risk of slightly-above-average weather. However, the evidence is clear that severe weather and moderate rainfall are also increasing. Increases in temperature are expected to produce more intense convection over land and a higher frequency of the most severe storms.

Increased evaporation

Over the course of the 20th century, evaporation rates have reduced worldwide this is thought by many to be explained by global dimming. As the climate grows warmer and the causes of global dimming are reduced, evaporation will increase due to warmer oceans. Because the world is a closed system this will cause heavier rainfall, with more erosion. This erosion, in turn, can in vulnerable tropical areas (especially in Africa) lead to desertification. On the other hand in other areas, increased rainfall lead to growth of forests in dry desert areas.

Scientists have found evidence that increased evaporation could result in more extreme weather as global warming progresses. The IPCC Third Annual Report says: "...global average water vapor concentration and precipitation are projected to increase during the 21st century. By the second half of the 21st century, it is likely that precipitation will have increased over northern mid- to high latitudes and Antarctica in winter. At low latitudes there are both regional increases and decreases over land areas. Larger year to year variations in precipitation are very likely over most areas where an increase in mean precipitation is projected."

Cost of more extreme weather

As the World Meteorological Organization explains, "recent increase in societal impact from tropical cyclones has largely been caused by rising concentrations of population and infrastructure in coastal regions." Pielke et al. (2008) normalized mainland U.S. hurricane damage from 1900–2005 to 2005 values and found no remaining trend of increasing absolute damage. The 1970s and 1980s were notable because of the extremely low amounts of damage compared to other decades. The decade 1996–2005 has the second most damage among the past 11 decades, with only the decade 1926–1935 surpassing its costs. The most damaging single storm is the 1926 Miami hurricane, with $157 billion of normalized damage.

The American Insurance Journal predicted that "catastrophe losses should be expected to double roughly every 10 years because of increases in construction costs, increases in the number of structures and changes in their characteristics." The Association of British Insurers has stated that limiting carbon emissions would avoid 80% of the projected additional annual cost of tropical cyclones by the 2080s. The cost is also increasing partly because of building in exposed areas such as coasts and floodplains. The ABI claims that reduction of the vulnerability to some inevitable effects of climate change, for example through more resilient buildings and improved flood defences, could also result in considerable cost-savings in the longterm.

Local climate change

In the northern hemisphere, the southern part of the Arctic region (home to 4,000,000 people) has experienced a temperature rise of 1 °C to 3 °C (1.8 °F to 5.4 °F) over the last 50 years. Canada, Alaska and Russia are experiencing initial melting of permafrost. This may disrupt ecosystems and by increasing bacterial activity in the soil lead to these areas becoming carbon sources instead of carbon sinks. A study (published in Science) of changes to eastern Siberia's permafrost suggests that it is gradually disappearing in the southern regions, leading to the loss of nearly 11% of Siberia's nearly 11,000 lakes since 1971At the same time, western Siberia is at the initial stage where melting permafrost is creating new lakes, which will eventually start disappearing as in the east. Furthermore, permafrost melting will eventually cause methane release from melting permafrost peat bogs.

Prior to March 2004, no tropical cyclone had been observed in the South Atlantic Ocean. The first Atlantic cyclone to form south of the equator hit Brazil on March 28, 2004 with 40 m/s (144 km/h) winds; although some Brazilian meteorologists deny that it was a hurricane. Monitoring systems may have to be extended 1,600 km (1,000 miles) further south. There is no agreement as to whether this hurricane is linked to climate change, but one climate model exhibits increased tropical cyclone genesis in the South Atlantic under global warming by the end of the 21st century.

Economic and social

Indigenous populations in high-latitude areas are already experiencing significant adverse impacts because of climate change. The impact of future climate change on human systems will likely be unevenly distributed. Africa is probably the most vulnerable continent to future climate change. Developing countries are probably more vulnerable to climate change than developed countries. With warming of 1-2°C above 1990-2000 levels, it is likely that key negative impacts

would be experienced in some regions, e.g., Arctic nations and small islands. In other regions, some population groups would be threatened by this level of warming, e.g., high-altitude communities and coastal-zone communities with significant levels of poverty. Above 2-3°C warming, it is likely that most countries would experience net negative impacts.

The total economic impacts of climate change are highly uncertain. Typical estimates of climate change impacts are of a change in gross world product of plus or minus a few percent. Small changes in gross world product could be associated with relatively large changes in national economies.

Insurance

An industry very directly affected by the risks is the insurance industry. According to a 2005 report from the Association of British Insurers, limiting carbon emissions could avoid 80% of the projected additional annual cost of tropical cyclones by the 2080s. A June 2004 report by the Association of British Insurers declared "Climate change is not a remote issue for future generations to deal with. It is, in various forms, here already, impacting on insurers' businesses now." It noted that weather risks for households and property were already increasing by 2-4 % per year due to changing weather, and that claims for storm and flood damages in the UK had doubled to over £6 billion over the period 1998–2003, compared to the previous five years. The results are raising insurance premiums, and the risk that in some areas flood insurance will become unaffordable for some.

Financial institutions, including the world's two largest insurance companies, Munich Re and Swiss Re, warned in a 2002 study that "the increasing frequency of severe climatic events, coupled with social trends" could cost almost US$ 150 billion each year in the next decade. These costs would, through increased costs related to insurance and disaster relief, burden customers, taxpayers, and industry alike.

In the United States, insurance losses have also greatly increased. According to Choi and Fisher (2003) each 1% increase in annual precipitation could enlarge catastrophe loss by as much as 2.8%. Gross increases are mostly attributed to increased population and property values in vulnerable coastal areas, though there was also an increase in frequency of weather-related events like heavy rainfalls since the 1950s.

Transport

Roads, airport runways, railway lines and pipelines, (including oil pipelines, sewers, water mains etc) may require increased maintenance and renewal as they become subject to greater temperature variation. Regions already adversely affected include areas of permafrost, which are subject to high levels of subsidence, resulting in buckling roads, sunken foundations, and severely cracked runways.

Effects on agriculture
Food

Climate change is expected to have a mixed effect on agriculture, with some regions benefitting from moderate temperature increases and others being negatively affected. Low-latitude areas are at most risk of suffering decreased crop yields. Mid- and high-latitude areas could see increased yields for temperature increases of up to 1-3°C (relative to the period 1980-99). According to the IPCC report, above 3°C of warming, global agricultural production might decline, but this statement is made with low to medium confidence. Most of the agricultural

studies assessed in the Report do not include changes in extreme weather events, changes in the spread of pests and diseases, or potential developments that may aid adaptation to climate change.

An article in the New Scientist describes how rice crops might be strongly affected by rising temperatures. At a 2005 Conference held by the Royal Society, the benefits of increased atmospheric carbon dioxide concentrations were said to be outweighed by the negative impacts of climate change.

Distribution of Impacts

In Iceland, rising temperatures have made possible the widespread sowing of barley, which was untenable twenty years ago. Some of the warming is due to a local (possibly temporary) effect via ocean currents from the Caribbean, which has also affected fish stocksBy the mid-21st century, in Siberia and elsewhere in Russia, climate change is expected to expand the scope for agriculture.[116] In East and Southeast Asia, crop yields could increase up to 20%, while in Central and South Asia, yields could decrease by up to 30%. In drier areas of Latin America, productivity of some important crops is expected to decline, while in temperate zones, soybean yields are expected to increase. In Northern Europe, climate change is expected to initially benefit crop yields. Subsistence and commercial agriculture are expected to be adversely affected by climate change in small islands. Without further adaptation, by 2030, production from agriculture is projected to decline over much of southern and eastern Australia, and parts of eastern New Zealand. Initial benefits are projected in western and southern areas of New Zealand. In North America, over the first few decades of this century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. According to a 2006 paper by Deschenes and Greenstone, predicted increases in temperature and precipitation will have virtually no effect on the most important crops in the US

In Africa, climate change is expected to severely compromise agricultural production and access to food. Africa's geography makes it particularly vulnerable, and seventy per cent of the population relies on rain-fed agriculture for their livelihoods. Tanzania's official report on climate change suggests that the areas that usually get two rainfalls in the year will probably get more, and those that get only one rainy season will get far less. The net result is expected to be that 33% less maize—the country's staple crop—will be grown. Alongside other factors, regional climate change - in particular, reduced precipitation - is thought to have contributed to the conflict in Darfur. The combination of decades of drought, desertification and overpopulation are among the causes of the conflict, because the Baggara Arab nomads searching for water have to take their livestock further south, to land mainly occupied by farming peoples.

Coasts and low-lying areas

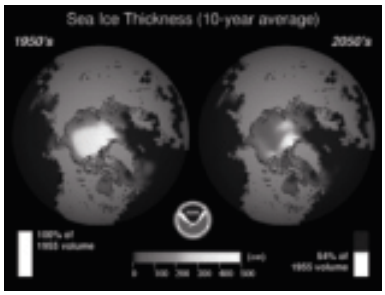
For historical reasons to do with trade, many of the world's largest and most prosperous cities are on the coast. In developing countries, the poorest often live on floodplains, because it is the only available space, or fertile agricultural land. These settlements often lack infrastructure such as dykes and early warning systems. Poorer communities also tend to lack the insurance, savings or access to credit needed to recover from disasters. With future climate change, it is likely that densely populated coastal areas will face increased risk of sea level rise and damages

due to more intense extreme weather events. Due to differences in adaptive capacity, adaptation of the coasts of developing countries will probably be more difficult than for the coasts of developed countries. A 2006 study by Nicholls and Tol considers the effects of sea level rise. The most vulnerable future worlds to sea-level rise appear to be the A2 and B2 [IPCC] scenarios, which primarily reflects differences in the socio-economic situation (coastal population, Gross Domestic Product (GDP) and GDP/capita), rather than the magnitude of sea-level rise. Small islands and deltaic settings stand out as being more vulnerable as shown in many earlier analyses. Collectively, these results suggest that human societies will have more choice in how they respond to sea-level rise than is often assumed. However, this conclusion needs to be tempered by recognition that we still do not understand these choices and significant impacts remain possible.

Migration

Some Pacific Ocean island nations, such as Tuvalu, are concerned about the possibility of an eventual evacuation, as flood defense may become economically unviable for them. Tuvalu already has an ad hoc agreement with New Zealand to allow phased relocation. In the 1990s a variety of estimates placed the number of environmental refugees at around 25 million. (Environmental refugees are not included in the official definition of refugees, which only includes migrants fleeing persecution.) The Intergovernmental Panel on Climate Change (IPCC), which advises the world's governments under the auspices of the UN, estimated that 150 million environmental refugees will exist in the year 2050, due mainly to the effects of coastal flooding, shoreline erosion and agricultural disruption (150 million means 1.5% of 2050's predicted 10 billion world population).

Figure-1
Northwest Passage



Arctic ice thicknesses changes from 1950s to 2050s simulated in one of GFDL's R30 atmosphere-ocean general circulation model experiments

Melting Arctic ice may open the Northwest Passage in summer, which would cut 5,000 nautical miles (9,000 km) from shipping routes between Europe and Asia. This would be of particular benefit for supertankers which are too big to fit through the Panama Canal and currently have to go around the tip of South America. According to the Canadian Ice Service, the amount of ice in Canada's eastern Arctic Archipelago decreased by 15% between 1969 and 2004.

In September 2007, the Arctic Ice Cap retreated far enough for the Northwest Passage to become navigable to shipping for the first time in recorded history.

In August, 2008, melting sea ice simultaneously opened up the Northwest Passage and the Northern Sea Route, making it possible to sail around the Arctic ice cap.[129] The Northwest Passage opened August 25, 2008, and the remaining tongue of ice blocking the Northern Sea Route dissolved a few days later. Because of Arctic shrinkage, the Beluga group of Bremen, Germany, announced plans to send

the first ship through the Northern Sea Route in 2009.

Development

The combined effects of global warming may have particularly harsh effects on people and countries without the resources to mitigate those effects. This may slow economic development and poverty reduction, and make it harder to achieve the Millennium Development Goals. In October 2004 the Working Group on Climate Change and Development, a coalition of development and environment NGOs, issued a report Up in Smoke on the effects of climate change on development. This report, and the July 2005 report Africa - Up in Smoke? predicted increased hunger and disease due to decreased rainfall and severe weather events, particularly in Africa. These are likely to have severe impacts on development for those affected.

Ecosystems

Unchecked global warming could affect most terrestrial ecoregions. Increasing global temperature means that ecosystems will change; some species are being forced out of their habitats (possibly to extinction) because of changing conditions, while others are flourishing. Secondary effects of global warming, such as lessened snow cover, rising sea levels, and weather changes, may influence not only human activities but also the ecosystem. Studying the association between Earth climate and extinctions over the past 520 million years, scientists from the University of York write, "The global temperatures predicted for the coming centuries may trigger a new 'mass extinction event', where over 50 per cent of animal and plant species would be wiped out."

Many of the species at risk are Arctic and Antarctic fauna such as polar bears and Emperor Penguins. In the Arctic, the waters of Hudson Bay are ice-free for three weeks longer than they were thirty years ago, affecting polar bears, which prefer to hunt on sea ice. Species that rely on cold weather conditions such as gyrfalcons, and Snowy Owls that prey on lemmings that use the cold winter to their advantage may be hit hard. Marine invertebrates enjoy peak growth at the temperatures they have adapted to, regardless of how cold these may be, and cold-blooded animals found at greater latitudes and altitudes generally grow faster to compensate for the short growing season. Warmer-than-ideal conditions result in higher metabolism and consequent reductions in body size despite increased foraging, which in turn elevates the risk of predation. Indeed, even a slight increase in temperature during development impairs growth efficiency and survival rate in rainbow trout.

Rising temperatures are beginning to have a noticeable impact on birds, and butterflies have shifted their ranges northward by 200 km in Europe and North America. Plants lag behind, and larger animals' migration is slowed down by cities and roads. In Britain, spring butterflies are appearing an average of 6 days earlier than two decades ago. A 2002 article in Nature surveyed the scientific literature to find recent changes in range or seasonal behaviour by plant and animal species. Of species showing recent change, 4 out of 5 shifted their ranges towards the poles or higher altitudes, creating "refugee species". Frogs were breeding, flowers blossoming and birds migrating an average 2.3 days earlier each decade; butterflies, birds and plants moving towards the poles by 6.1 km per decade. A 2005 study concludes human activity is the cause of the temperature rise and resultant changing species behaviour, and links these effects with the predictions of climate models to provide

validation for them. Scientists have observed that Antarctic hair grass is colonizing areas of Antarctica where previously their survival range was limited.

Mechanistic studies have documented extinctions due to recent climate change: McLaughlin et al. documented two populations of Bay checkerspot butterfly being threatened by precipitation change. Parmesan states, "Few studies have been conducted at a scale that encompasses an entire species"and McLaughlin et al. agreed "few mechanistic studies have linked extinctions to recent climate change." Daniel Botkin and other authors in one study believe that projected rates of extinction are overestimated. Many species of freshwater and saltwater plants and animals are dependent on glacier-fed waters to ensure a cold water habitat that they have adapted to. Some species of freshwater fish need cold water to survive and to reproduce, and this is especially true with Salmon and Cutthroat trout. Reduced glacier runoff can lead to insufficient stream flow to allow these species to thrive. Ocean krill, a cornerstone species, prefer cold water and are the primary food source for aquatic mammals such as the Whale. Alterations to the ocean currents, due to increased freshwater inputs from glacier melt, and the potential alterations to thermohaline circulation of the worlds oceans, may affect existing fisheries upon which humans depend as well.

The white lemuroid possum, only found in the mountain forests of northern Queensland, has been named as the first mammal species to be driven extinct by man-made global warming. The White Possum has not been seen in over three years. These possums cannot survive extended temperatures over 30 °C (86 °F), which occurred in 2005. A final expedition to uncover any surviving White Possums is scheduled for 2009.

Forests

Pine forests in British Columbia have been devastated by a pine beetle infestation, which has expanded unhindered since 1998 at least in part due to the lack of severe winters since that time; a few days of extreme cold kill most mountain pine beetles and have kept outbreaks in the past naturally contained. The infestation, which (by November 2008) has killed about half of the province's lodge pole pines (33 million acres or 135,000 km2) is an order of magnitude larger than any previously recorded outbreak and passed via unusually strong winds in 2007 over the continental divide to Alberta. An epidemic also started, be it at a lower rate, in 1999 in Colorado, Wyoming, and Montana. The United States forest service predicts that between 2011 and 2013 virtually all 5 million acres (20,000 km2) of Colorado's lodge pole pine trees over five inches (127 mm) in diameter will be lost

As the northern forests are a carbon sink, while dead forests are a major carbon source, the loss of such large areas of forest has a positive feedback on global warming. In the worst years, the carbon emission due to beetle infestation of forests in British Columbia alone approaches that of an average year of forest fires in all of Canada or five years worth of emissions from that country's transportation sources.

Besides the immediate ecological and economic impact, the huge dead forests provide a fire risk. Even many healthy forests appear to face an increased risk of forest fires because of warming climates. The 10-year average of boreal forest burned in North America, after several decades of around 10,000 km² (2.5 million acres), has increased steadily since 1970 to more than 28,000 km² (7 million acres) annually.. Though this change may be due in part to changes in forest management practices, in the western

U.S., since 1986, longer, warmer summers have resulted in a fourfold increase of major wildfires and a six fold increase in the area of forest burned, compared to the period from 1970 to 1986. A similar increase in wildfire activity has been reported in Canada from 1920 to 1999. Forest fires in Indonesia have dramatically increased since 1997 as well. These fires are often actively started to clear forest for agriculture. They can set fire to the large peat bogs in the region and the CO2 released by these peat bog fires has been estimated, in an average year, to be 15% of the quantity of CO2 produced by fossil fuel combustion.

Mountains

Mountains cover approximately 25 percent of earth's surface and provide a home to more than one-tenth of global human population. Changes in global climate pose a number of potential risks to mountain habitats .Researchers expect that over time, climate change will affect mountain and lowland ecosystems, the frequency and intensity of forest fires, the diversity of wildlife, and the distribution of water. Studies suggest that a warmer climate in the United States would cause lower-elevation habitats to expand into the higher alpine zone. Such a shift would encroach on the rare alpine meadows and other high-altitude habitats. High-elevation plants and animals have limited space available for new habitat as they move higher on the mountains in order to adapt to long-term changes in regional climate.

Changes in climate will also affect the depth of the mountains snow packs and glaciers. Any changes in their seasonal melting can have powerful impacts on areas that rely on freshwater runoff from mountains. Rising temperature may cause snow to melt earlier and faster in the spring and shift the timing and distribution of runoff. These changes could affect the availability of freshwater for natural systems and human uses.

Ecological productivity

According to a 2003 paper by Smith and Hitz, it is reasonable to assume that the relationship between increased global mean temperature and ecosystem productivity is parabolic. Higher carbon dioxide concentrations will favorably affect plant growth and demand for water. Higher temperatures could initially be favorable for plant growth. Eventually, increased growth would peak then decline. According to the IPCC report, a global average temperature increase exceeding 1.5-2.5°C (relative to the period 1980-99), would likely have a predominantly negative impact on ecosystem goods and services, e.g., water and food supply. Research done by the Swiss Canopy Crane Project suggests that slow-growing trees only are stimulated in growth for a short period under higher CO2 levels, while faster growing plants like liana benefit in the long term. In general, but especially in rainforests, this means that liana become the prevalent species; and because they decompose much faster than trees their carbon content is more quickly returned to the atmosphere. Slow growing trees incorporate atmospheric carbon for decades.

Water scarcity

Sea level rise is projected to increase salt-water intrusion into groundwater in some regions, affecting drinking water and agriculture in coastal zones. Increased evaporation will reduce the effectiveness of reservoirs. Increased extreme weather means more water falls on hardened ground unable to absorb it, leading to flash floods instead of a replenishment of soil moisture or groundwater levels. In some areas, shrinking

glaciers threaten the water supply. The continued retreat of glaciers will have a number of different effects. In areas that are heavily dependent on water runoff from glaciers that melt during the warmer summer months, a continuation of the current retreat will eventually deplete the glacial ice and substantially reduce or eliminate runoff. A reduction in runoff will affect the ability to irrigate crops and will reduce summer stream flows necessary to keep dams and reservoirs replenished. This situation is particularly acute for irrigation in South America, where numerous artificial lakes are filled almost exclusively by glacial melt. Central Asian countries have also been historically dependent on the seasonal glacier melt water for irrigation and drinking supplies. In Norway, the Alps, and the Pacific Northwest of North America, glacier runoff is important for hydropower. Higher temperatures will also increase the demand for water for the purposes of cooling and hydration.

In the Sahel, there has been an unusually wet period from 1950 until 1970, followed by extremely dry years from 1970 to 1990. From 1990 until 2004 rainfall returned to levels slightly below the 1898–1993 average, but year-to-year variability was high.

Health

Climate change currently contributes to the burden of disease and premature deaths. Economic development will affect how effective adaptation to climate change will be. According to the IPCC report, it is likely that:

1. climate change will bring some benefits, such as reduced cold deaths.

2. the balance of positive and negative health impacts will vary from one location to another.

3. adverse health impacts will be greatest in low-income countries.

4. the negative health impacts of climate change will outweigh the benefits, especially in developing countries. Some examples of negative health impacts include increased malnutrition, increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts, and increased frequency of cardio-respiratory diseases.

According to a 2009 study by UCL academics, climate change and global warming pose the biggest threat to human health in the 21st century.

Direct effects of temperature rise

The most direct effect of climate change on humans might be the impacts of hotter temperatures themselves. Extreme high temperatures increase the number of people who die on a given day for many reasons: people with heart problems are vulnerable because one's cardiovascular system must work harder to keep the body cool during hot weather, heat exhaustion, and some respiratory problems increase. Global warming could mean more cardiovascular diseases, doctors warn. Higher air temperature also increase the concentration of ozone at ground level. In the lower atmosphere, ozone is a harmful pollutant. It damages lung tissues and causes problems for people with asthma and other lung diseases.

Rising temperatures have two opposing direct effects on mortality: higher temperatures in winter reduce deaths from cold; higher temperatures in summer increase heat-related deaths. The net local impact of these two direct effects depends on the current climate in a particular area. Palutikof et al. (1996) calculate that in England and Wales for a 1 °C temperature rise the reduced deaths from cold outweigh the increased deaths from heat, resulting in a

reduction in annual average mortality of 7000, while Keatinge et al. (2000) "suggest that any increases in mortality due to increased temperatures would be outweighed by much larger short term declines in cold related mortalities. Cold-related deaths are far more numerous than heat-related deaths in the United States, Europe, and almost all countries outside the tropics. During 1979–1999, a total of 3,829 deaths in the United States were associated with excessive heat due to weather conditions, while in that same period a total of 13,970 deaths were attributed to hypothermia. In Europe, mean annual heat related mortalities are 304 in North Finland, 445 in Athens, and 40 in London, while cold related mortalities are 2457, 2533, and 3129 respectively. According to Keatinge et al. (2000), "populations in Europe have adjusted successfully to mean summer temperatures ranging from 13.5°C to 24.1°C, and can be expected to adjust to global warming predicted for the next half century with little sustained increase in heat related mortality."

A government report shows decreased mortality due to recent warming and predicts increased mortality due to future warming in the United Kingdom. The 2003 European heat wave killed 22,000–35,000 people, based on normal mortality rates. Peter A. Stott from the Hadley Centre for Climate Prediction and Research estimated with 90% confidence that past human influence on climate was responsible for at least half the risk of the 2003 European summer heat-wave.

Spread of disease

Global warming may extend the favorable zones for vectors conveying infectious disease such as dengue fever West Nile virus, and malaria. In poorer countries, this may simply lead to higher incidence of such diseases. In richer countries, where such diseases have been eliminated or kept in check by vaccination, draining swamps and using pesticides, the consequences may be felt more in economic than health terms. The World Health Organization (WHO) says global warming could lead to a major increase in insect-borne diseases in Britain and Europe, as northern Europe becomes warmer, ticks—which carry encephalitis and Lyme disease—and sand flies—which carry visceral leishmaniasis—are likely to move in. However, malaria has always been a common threat in European past, with the last epidemic occurring in the Netherlands during the 1950s. In the United States, Malaria has been endemic in as much as 36 states (including Washington, North Dakota, Michigan and New York) until the 1940s. By 1949, the country was declared free of malaria as a significant public health problem, after more than 4,650,000 house DDT spray applications had been made.

The World Health Organization estimates 150,000 deaths annually "as a result of climate change", of which half in the Asia-Pacific region. In April 2008, it reported that, as a result of increased temperatures, the number of malaria infections is expected to increase in the highland areas of Papua New Guinea.

Children

Anticipated direct health consequences of climate change include injury and death from extreme weather events and natural disasters, increases in climate-sensitive infectious diseases, increases in air pollution–related illness, and more heat-related, potentially fatal, illness. Within all of these categories, children have increased vulnerability compared with other groups. On 2008-04-29, a UNICEF UK Report found that

global warming is already reducing the quality of the world's most vulnerable children's lives and making it more difficult to meet the UN Millennium Development Goals. Global warming will reduce access to clean water and food supplies, particularly in Africa and Asia. Disasters, violence and disease are expected to be more frequent and intense, making the future of the world's poorest children bleaker.

Security

The Military Advisory Board, a panel of retired U.S. generals and admirals released a report entitled "National Security and the Threat of Climate Change." The report predicts that global warming will have security implications, in particular serving as a "threat multiplier" in already volatile regions. Britain's Foreign Secretary Margaret Beckett argues that "An unstable climate will exacerbate some of the core drivers of conflict, such as migratory pressures and competition for resources." And several weeks earlier, U.S. Senators Chuck Hagel (R-NB) and Richard Durbin (D-IL) introduced a bill in the U.S. Congress that would require federal intelligence agencies to collaborate on a National Intelligence Estimate to evaluate the security challenges presented by climate change.

In November 2007, two Washington think tanks, the established Center for Strategic and International Studies and the newer Center for a New American Security, published a report analyzing the worldwide security implications of three different global warming scenarios. The report considers three different scenarios, two over a roughly 30 year perspective and one covering the time up to 2100. Its general results conclude that flooding "...has the potential to challenge regional and even national identities. Armed conflict between nations over resources, such as the Nile and its tributaries, is likely..." and that "Perhaps the most worrisome problems associated with rising temperatures and sea levels are from large-scale migrations of people -- both inside nations and across existing national borders."

A 2009 study questions the assumption that rising temperatures and violence are linked. Richard Tol and Sebastian Wagner collected data on climate and conflict in Europe between the years 1000 and 2000. They concluded that until the mid-18th century, there was a significant negative correlation between the number of conflicts and average temperature, but after that no statistically meaningful relationship can be observed. Tol and Wagner argue that the relationship between warfare and colder weather disappears around the time of the industrial revolution, when agriculture and transport improve dramatically. The Economist suggests that the lesson of their research is that climate-induced conflict can be minimised by continuing the process of crop improvement.

Staying Green in a Tough Economic Climate

Most annual reports make a respectable nod to "sustainable" these days--it's easy for companies to devote serious resources to green growth when the economy is chugging along. Sir Stuart Rose, chief executive of the British retail giant Marks & Spencer, says his company is making great leaps forward with Plan A--its ambitious 100-point plan to be carbon neutral and send no waste to landfill by 2012. But what happens to those good intentions when business gets rocky and shareholders see red, not green? What are the true bottom-line trade-offs? Will today's noble initiatives fade to historic footnotes when companies struggle to survive? On January

9, 2008, the London stock market reacted strongly to a 12-week Marks & Spencer trading statement: Same-store sales, excluding new space, were down by 2.2% compared with the previous year. Our share price fell 18%, taking £1.6 billion off the value of our business. In light of increased business uncertainty and fragile consumer confidence, it might have been tempting to quietly shelve Plan A, our 100-point, five-year eco-plan. We could have heeded critics who said, "Times are tough, best ditch the fluffy stuff." But we didn't. We started Plan A last year, to make M&S carbon neutral and send no waste to landfill from our operations by 2012. The plan extends to sustainable raw materials sourcing, sets new standards in ethical trading, and helps customers and colleagues lead healthier lives.

Despite the tough consumer climate and the reaction to our sales results, we are sticking to Plan A. There are compelling commercial--as well as moral--reasons to do so. Take the early results it's generating. Our "Wash at 30" campaign, which encourages consumers to wash their clothing at a lower temperature than used to be considered the norm, has saved an estimated 25,000 tons of carbon dioxide. We have reduced C02 emissions by an additional 55,000 tons by switching 23% of electricity to renewable resources. Toward our goal of zero waste to landfill, 75% of the construction waste from our store refurbishment program is now recycled. While we've estimated Plan A could cost around £200 million over five years, we haven't actually done a hard cost-benefit analysis. What we know is that individual decisions within Plan A need to make financial sense. For example, various initiatives--recycling clothes hangers, reducing packaging, and encouraging reusable carrier bags instead of plastic--are saving us millions of pounds, reducing landfill waste, and decreasing electricity consumption.

Progress against Plan A is closely monitored because we regularly consult with a wide range of NGOs. The plan has also gained NGO recognition and was recently awarded the World Environment Center gold medal for sustainable business practices. We have a series of key public reporting dates with NGOs so that we can take their recommendations and ask for help. We have also deliberately tied Plan A reporting to our financial reporting schedule so that our stakeholders know when to expect to hear from us, and we expect to be held accountable to our commitments.

Cutting back would also be a commercial mistake. A 2007 M&S customer survey said that 75% of British consumers are interested in green issues. Last November, in a survey which scored M&S with the best reputation in British business, the Confederation of British Industry concluded that customers will pay a premium for a great reputation, and that, as far as M&S is concerned, Plan A is already contributing positively to our wider standing. We've also taken some tough decisions not to do certain things. We decided not to put wind turbines on the roof of our first eco-store, a store designed entirely around green principles, because they wouldn't have been capable of generating sufficient power in that location and it would have been too expensive to build and maintain them. Symbolic perhaps, but not economic. So, responsible business is good business, provided we don't get too far ahead of our customers. I think half a step is about right: Any more and you can't sell to them; any less and you lose the lead. Global Warming Consensus is growing among scientists, governments, and business that they must act fast to combat climate change. This has already sparked efforts to limit CO2 emissions. Many companies are now preparing for a carbon-constrained world.

The idea that the human species could alter something as huge and complex as the earth's climate was once the subject of an esoteric scientific debate. But now even attorneys general more used to battling corporate malfeasance are taking up the cause. On July 21, New York Attorney General Eliot Spitzer and lawyers from seven other states sued the nation's largest utility companies, demanding that they reduce emissions of the gases thought to be warming the earth. Warns Spitzer: "Global warming threatens our health, our economy, our natural resources, and our children's future. It is clear we must act."

The manoeuvres of eight mostly Democratic AGs could be seen as a political attack. But their suit is only one tiny trumpet note in a growing bipartisan call to arms. "The facts are there," says Senator John McCain (R-Ariz.). "We have to educate our fellow citizens about climate change and the danger it poses to the world." In January, the European Union will impose mandatory caps on carbon dioxide and other gases that act like a greenhouse over the earth, and will begin a market-based system for buying and selling the right to emit carbon. By the end of the year, Russia may ratify the Kyoto Protocol, which makes CO2 reductions mandatory among the 124 countries that have already accepted the accord. Some countries are leaping even further ahead. Britain has vowed to slash emissions by 60% by 2050. Climate change is a greater threat to the world than terrorism, argues Sir David King, chief science adviser to Prime Minister Tony Blair: "Delaying action for a decade, or even just years, is not a serious option. There are naysayers. The Bush Administration flatly rejects Kyoto and mandatory curbs, arguing that such steps will cripple the economy. Better to develop new low-carbon technologies to solve problems if and when they appear, says Energy Secretary Spencer Abraham. And a small group of scientists still argues there is no danger. "We know how much the planet is going to warm," says the Cato Institute's Patrick J. Michaels. "It is a small amount, and we can't do anything about it.But the growing consensus among scientists and governments is that we can -- and must -- do something. Researchers under the auspices of the National Academy of Sciences and the Intergovernmental Panel on Climate Change (IPCC) have pondered the evidence and concluded that the earth is warming, that humans are probably the cause, and that the threat is real enough to warrant an immediate response. "There is no dispute that the temperature will rise. It will," says Donald Kennedy, editor-in-chief of Science. "The disagreement is how much." Indeed, "there is a real potential for sudden and perhaps catastrophic change," says Eileen Claussen, president of the Pew Center on Global Climate Change: "The fact that we are uncertain may actually be a reason to act sooner rather than later." Plus, taking action brings a host of ancillary benefits. The main way to cut greenhouse-gas emissions is simply to burn less fossil fuel. Making cars and factories more energy-efficient and using alternative sources would make America less dependent on the Persian Gulf and sources of other imported oil. It would mean less pollution. And many companies that have cut emissions have discovered, often to their surprise, that it saves money and spurs development of innovative technologies. "It's impossible to find a company that has acted and has not found benefits," says Michael Northrop, co-creator of the Climate Group, a coalition of companies and governments set up to share such success stories. That's why there has been a rush to fill the leadership vacuum left by Washington. "States have stepped up to fill this policy void, as much out of economic self-interest as fear of devastating climate changes," says Kenneth A. Colburn, executive director of

Northeast States for Coordinated Air Use Management. Warning of flooded coasts and crippled industries, Massachusetts unveiled a plan in May to cut emissions by 10% by 2020. In June, California proposed 30% cuts in car emissions by 2015. Many other states are weighing similar actions.

Curbing Carbon

Remarkably, business is far ahead of Congress and the White House. Some CEOs are already calling for once-unthinkable steps. "We accept that the science on global warming is overwhelming," says John W. Rowe, chairman and CEO of Exelon Corp. (EXC) "There should be mandatory carbon constraints." Exelon, of course, would likely benefit as the nation's largest operator of commercial nuclear power plants. But many other companies also are planning for that future. American Electric Power Co. (AEP) once fought the idea of combating climate change. But in the late 1990s, then-CEO E. Linn Draper Jr. pushed for a strategy shift at the No. 1 coal-burning utility -- preparing for limits instead of denying that global warming existed. It was a tough sell to management. Limits on carbon emissions threaten the whole idea of burning coal. But Draper prevailed. Why? "We felt it was inevitable that we were going to live in a carbon-constrained world," says Dale E. Heydlauff, AEP's senior vice-president for environmental affairs.Now, AEP is trying to accumulate credits for cutting CO2. It's investing in renewable energy projects in Chile, retrofitting school buildings in Bulgaria for greater efficiency, and exploring ways to burn coal more cleanly. Scores of other companies are also taking action -- and seeing big benefits. DuPont (DD) has cut its greenhouse-gas emissions by 65% since 1990, saving hundreds of millions of dollars in the process. Alcoa Inc. (AA) is aiming at a 25% cut by 2010. General Electric Co. (GE) is anticipating growing markets for its wind power division and for more energy-efficient appliances. And General Motors Corp. (GM) is spending millions to develop hydrogen-powered cars that don't emit CO2. A low-carbon economy "could really change our industry," says Fred Sciance, manager of GM's global climate issues team. As Exelon knows, the need for carbon-free power could even mean a boost for advanced nuclear reactors, which produce electricity without any greenhouse-gas emissions. Global warming could change other industries, too. Even if the world manages to make big cuts in emissions soon, the earth will still warm several more degrees in coming decades, most climate scientists believe. That could slash agricultural yields, raise sea levels, and bring more extreme weather.

Indeed, there is surprising consensus about the policies needed to spur innovation and fight global warming. The basic idea: mandatory reductions or taxes on carbon emissions, combined with a worldwide emissions-trading program. Here's how it could work: Imagine that each company in a particular sector is required to cut emissions by 20%. The company could meet the target on its own by becoming more energy efficient or by switching from fossil fuels to alternatives. But it could also simply buy the needed reductions on the open market from others who have already cut emissions more than required, and who thus have excess emissions to sell. Under a sophisticated worldwide carbon-trading system, governments and companies could also get sellable credits for planting trees to soak up carbon or for investing in, say, energy efficient and low-carbon technologies in the developing world. As a result, there is a powerful incentive for everyone to find the lowest-cost and most effective cuts -- and to move to lower-carbon technologies.

The Challenges

Such clear policy signals should bring major efficiency gains. Even 30% to 40% reductions in emissions by 2020 are possible, says Northrop. After that, he suggests, shifts to new energy technologies "can get the other 35% to 40% that we need to get to the low-carbon emission future."

The good news is that the world sees the threat and has begun to respond. The bad news is the magnitude of the task. Rising CO2 levels in the atmosphere can't be slowed or reduced if only a few countries -- or even all the industrialized nations -- take action. The world must also figure out a way to permit growth in China, India, and other developing nations while lowering consumption of coal, gasoline, and other fossil fuels. "It's hard to think of a public policy issue that is harder than this one," says economist Jeffrey D. Sachs, director of Columbia University's Earth Institute.

Developing countries are responsible for just over one-third of the world's greenhouse-gas emissions. But they emit less than one-fifth as much per person as do the industrialized nations. That will increase as their citizens buy more cars and consume more energy. By 2100, these countries will emit two or three times as much as the developed world, experts predict.

The Bush Administration and Congress have seized upon this issue as one reason for rejecting the Kyoto Protocol, which doesn't include the developing world. But international negotiators are beginning to talk about a plan that would go beyond Kyoto. The first step: showing that the industrialized world is serious about leading the way. That's one of the motivations behind Britain's vow to slash emissions by 60%, for example. Britain knows it can't solve this global problem by itself. But committing to reducing CO2 "is the right thing to do," says British Energy Minister Stephen Timms. It will also keep the country from becoming dependent on foreign oil when its North Sea oil fields start to run dry in a few years.

The next step is to help the developing world adopt new technologies. China and other nations could avoid the West's era of gas-guzzlers and dirty power plants by jumping to highly efficient clean coal plants and hybrid or advanced diesel cars. What's needed, experts say, are incentives to stimulate companies to make investments in advanced technology in developing countries. Once an international carbon-trading system is put in place, suggests Elliot Diringer, director of international strategies at the Pew Center on Global Climate Change, "we can reduce our own costs in the U.S. by allowing our companies to get the benefit of low-cost emissions abroad."

Still, even if the developing world comes on board, staggering reductions in emissions are needed. Consider the math. For the past 450,000 years, the amount of carbon dioxide in the atmosphere has stayed below 290 parts per million (ppm). Now, we are spewing out more than 7 gigatons of carbon a year and large amounts of other greenhouse gases such as methane. As a result, the CO2 levels in the air have climbed past 370 ppm. With no action, those levels could jump to 800 to 1,000 ppm by the end of the century. "We are already in dire straits," warns Columbia University geophysicist Klaus S. Lackner.

The Science

Can serious consequences be prevented? The British government, many scientists, and some executives are urging an all-out effort to keep the earth from warming more than two degrees Celsius. "The consequences of changes above two degrees are so dreadful that we need to avoid

it," says BP's Mottershead. To hit that target, scientists calculate that CO2 concentrations in the atmosphere must be kept from reaching 550 ppm -- twice the preindustrial level. Getting there may require cutting the world's per capita emissions in half by 2100.

Of course, there is great uncertainty surrounding the science of global warming. No one can really know the size and consequences of climate change. "Without a doubt, it will be a very different world -- a much warmer world," says David S. Battisti, atmospheric scientist at the University of Washington. But how much warmer? Which regions will be better or worse off? Will there be more floods and droughts? There's even a chance of surprises beyond the scary predictions of some computer models. "What are worrisome are the unknown unknowns," says Daniel P. Schrag, director of the Laboratory for Geochemical Oceanography at Harvard University. "We are performing an experiment that hasn't been done in millions of years, and no one knows exactly what's going to happen."

What scientists do know is that carbon dioxide and a number of other gases act like the roof of a greenhouse. Energy from the sun passes through easily. Some of the warmth that normally would be radiated back out to space is trapped, however, warming the planet. With no greenhouse gases at all in the atmosphere, we would freeze. The earth's average temperature would be a cold -17C, not the relatively balmy 14C it is today.

But the atmosphere is fiendishly complicated. If an increase in greenhouse gases also makes the sky cloudier, the added clouds may cool the surface enough to offset warming from CO2. Tiny particles from pollution also exert warming or cooling effects, depending on where they are in the atmosphere. Naysayers argue that it's just too soon to tell if greenhouse gases will significantly change the climate.

Yet the climate is changing. In the past 100 years, global temperatures are up 0.6 degrees Celsius. The past few decades are the warmest since people began keeping temperature records -- altering the face of the planet.

For instance, the Qori Kalis glacier in Peru is shrinking at a rate of 200 meters per year, 40 times as fast as in 1978. It's just one of hundreds of glaciers that are vanishing. Ice is disappearing from the Arctic Ocean and Greenland. More than a hundred species of animals have been spotted moving to cooler regions, and spring starts sooner for more than 200 others. "It's increasingly clear that even the modest warming today is having large effects on ecosystems," says ecologist Christopher B. Field of the Carnegie Institution. "The most compelling impact is the 10% decreasing yield of corn in the Midwest per degree [of warming.]"

More worrisome, scientists have learned from the past that seemingly small perturbations can cause the climate to swing rapidly and dramatically. Data from ice cores taken from Greenland and elsewhere reveal that parts of the planet cooled by 10 degrees Celsius in just a few decades about 12,700 years ago. Five thousand years ago, the Sahara region of Africa was transformed from a verdant lake-studded landscape like Minnesota's to barren desert in just a few hundred years. The initial push -- a change in the earth's orbit -- was small and very gradual, says geochemist Peter B. deMenocal of Columbia University's Lamont-Doherty Earth Observatory. "But the climate response was very abrupt -- like flipping a switch."

The earth's history is full of such abrupt climate changes. Now many scientists fear that the current buildup of greenhouse gases could

also flip a global switch. "To take a chance and say these abrupt changes won't occur in the future is sheer madness," says Wallace S. Broecker, earth scientist at Lamont-Doherty. "That's why it is absolutely foolhardy to let CO2 go up to 600 or 800 ppm."

Indeed, Broecker has helped pinpoint one switch involving ocean currents that circulate heat and cold. If this so-called conveyor shuts down, the Gulf Stream stops bringing heat to Europe and the U.S. Northeast. This is not speculation. It has happened in the past, most recently 8,200 years ago.

Can it happen again? May be. A recent Pentagon report tells of a "plausible...though not the most likely" scenario, in which the conveyor shuts off. "Such abrupt climate change...could potentially destabilize the geopolitical environment, leading to skirmishes, battles, and even war," it warns.

There are already worrisome signs. The global conveyor is driven by cold, salty water in the Arctic, which sinks to the bottom and flows south. If the water isn't salty enough -- thus heavy enough -- to sink, the conveyor shuts down. Now, scientists are discovering that Arctic and North Atlantic waters are becoming fresher because of increased precipitation and melting. "Over the past four decades, the subpolar North Atlantic has become dramatically less salty, while the tropical oceans have become saltier," observed William B. Curry of the Woods Hole Oceanographic Institution in recent congressional testimony. "These salinity changes are unprecedented in the relatively short history of the science of oceanography."

If the global switch does flip, an Ice Age won't descend upon Europe, scientists now believe. But that doesn't mean the consequences won't be severe. The sobering lesson from the past is that the climate is a temperamental beast. And now, with the atmosphere filling with greenhouse gases, "the future may have big surprises in store," says Harvard's Schrag.

In some scenarios, the ice on Greenland eventually melts, causing sea levels to rise 18 feet. Melt just the West Antarctic ice sheet as well, and sea levels jump another 18 feet. Currently shrinking glaciers may mean threats to water supplies for farmers and cities. Meanwhile, higher temperatures can cut crop yields, inhibit rice germination, and devastate biologically vital ecosystems like coral reefs. A paper in the July 16 issue of Science suggests that increasing CO2 levels in the ocean could affect the growth of marine life, with consequences for the oceanic food chain