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Global Trends of Fossil Fuel Reserves and Climate Change in the 21st Century

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1. Introduction

Today's energy markets are dominated by a substantial increase in energy demand due to the strong economic growth in the developing countries especially in China and India. At the same time it is also observed that the capacity to deliver fossil energy may be limited due to limited production capacity and lack of infrastructure such as pipeline, refining and terminal capacities (CERA, A global sense of energy insecurity). A number of nations are concerned with their security of supply with respect to delivery of power, oil and gas, and we see a development toward more nationalization of energy production and distribution in several nations. Huge investments in production capacity and infrastructure are needed in many countries to secure necessary access to energy (*IEA, World Energy Outlook, 2004, p 32*).

Emissions of carbon dioxide due to our use of fossil energy will change the climate and the temperature is estimated to increase by 2 to 6^{o} Celsius within year 2100, which is a tremendous increase from our current average temperature of 1.7^{o} Celsius (IPCC). This will probably cause huge changes to our society, both positive and negative, but the total impact on our society is currently very uncertain.

The global population is expected to increase by 30% the next 25 years, where 80-90% of the increase is expected to be in developing countries (*IEA, World Energy Outlook 2004, p 43-46*). To be able to establish a sustainable global development, with growth in population and living standard, it will probably be necessary to develop renewable and cleaner energy sources, improved energy efficiency and mechanisms that make it attractive to utilize new technology.

The 30 year update claims that the global system is currently in an un-sustainable situation, and that there are limits to growth on our planet – on resources, food, environment, and also in the population the earth can supply over time. If we do not act soon to establish a sustainable world, we will probably face enormous challenges in providing goods, energy and food to the population and we will probably experience recession, hunger, conflicts, reduced living conditions and maybe a significant reduction in population.

This study describes some of the background for the scenario analysis such as: potential impacts of changes in the energy resource situation, both fossil and renewable, impact on global climate, important geo-political issues and major global trends which can have an impact on the energy as well as climate.

2. Global trends of fossil fuel reserves

United States, Russia and China are leading producers and consumers of World Energy. These three countries together produced 31% and consumed 41% world total energy as per International Energy Agency (IEA) 1999. United Sates consumed three times the energy than China, the second largest consumer of World. Fossil fuels will remain the most important energy source, at least until 2030, and the use of oil, gas and coal is expected to grow in volume (IEA, 2009) over this period. Coal is not scarce, but is problematic for pollution and climate change reasons. The production costs of oil continue to rise with the expansion of the share of deepwater exploration in the supply (IEA, 2008). Although coal and gas are abundantly available, environmental and logistical reasons prevent a substantial shift away from oil to these energy sources.

Fossil fuel reserves are concentrated in a small number of countries. 80 % of the coal reserves are located in just six countries; the European Union (EU) has 4 % of the global stock. The EU share of the world's gas reserves decreased from 4.6 % in 1980 to 1.3 % in 2009. These reserves are expected to be exhausted before 2030. More than half of the global stock is found in only three countries: Iran, Qatar and Russia (24 % in 2009), which is a major gas supplier for the EU. Ten countries (of which eight are OPEC members) have 80 % of the world's oil reserves. Some of these countries may exercise their power to restrict supply or influence the price (NIC, 2008). EU dependence on imported fossil fuels is slowly rising and presently amounts to about 55 %. Some EU countries (for instance Estonia, Italy, France and Sweden) have sizeable oil shale stocks. Reduced foreign supply may encourage them to exploit these sources. The Arctic region is expected to contain a substantial amount of oil, probably up to 90 billion barrels (EU: about 12 billion barrels).

2.1 Will fossil fuel reserves be effectively depleted by 2050?

Crude oil, coal and gas are the main resources for world energy supply. The size of fossil fuel reserves and the dilemma that when non-renewable energy will be diminished, is a fundamental and doubtful question that needs to be answered. Here a new formula for calculating when fossil fuel reserves are likely to be depleted is presented along with an econometrics model to demonstrate the relationship between fossil fuel reserves and some main variables (*Shahriar Shafiee et.al. 2009*). The new formula is modified from the Klass model and thus assumes a continuous compound rate and computes fossil fuel reserve depletion times for oil, coal and gas of approximately 35, 107 and 37 years, respectively. This means that coal reserves are available up to 2112, and will be the only fossil fuel remaining after 2042.

In the Econometrics model, the main exogenous variables affecting oil, coal and gas reserve trends are their consumption and respective prices between 1980 and 2006. The models for oil and gas reserves unexpectedly show a positive and significant relationship with consumption, while presenting a negative and significant relationship with price. The econometrics model for coal reserves, however, expectedly illustrates a negative and significant relationship with consumption and a positive and significant relationship with price. Consequently, huge reserves of coal and low-level coal prices in comparison to oil and gas make coal one of the main energy substitutions for oil and gas in the future, under the assumption of coal as a clean energy source.

Fossil fuels play a crucial role in the world energy market *(Goldemberg, 2006)*. The world's energy market worth around 1.5 trillion dollars is still dominated by fossil fuels. The World Energy Outlook (WEO) 2007 claims that energy generated from fossil fuels will remain the major source and is still expected to meet about 84% of energy demand in 2030. There is worldwide research into other reliable energy resources to replace fossil fuel, as they diminish; this is mainly being driven due to the uncertainty surrounding the future supply of fossil fuels. It is expected, however, that the global energy market will continue to depend on fossil fuels for at least the next few decades.

World oil resources are judged to be sufficient to meet the projected growth in demand until 2030, with output becoming more concentrated in Organization of Petroleum Exporting Countries on the assumption that the necessary investment is forthcoming IEA, 2007. According to WEO 2007 oil and gas supplies are estimated to escalate from 36 million barrels per day in 2006 to 46 million barrels per day in 2015, reaching 61 million barrels per day by 2030. In addition, oil and gas reserves are forecast at about 1300 billion barrels and 6100 trillion cubic feet in 2006, respectively (BP, 2007). The World Energy Council (WEC) in 2007 estimated recoverable coal reserves of around 850 billion tonne in 2006.

Table 1 shows the distribution of remaining reserves of fossil fuels. Firstly, as seen in Table 1, coal constitutes approximately 65% of the fossil fuel reserves in the world, with the remaining 35% being oil and gas. Secondly, while the size and location of reserves of oil and gas are limited in the Middle East, coal remains abundant and broadly distributed around the world. Economically recoverable reserves of coal are available in more than 70 countries worldwide and in each major world region. In other words, coal reserves are not limited to mainly one location, such as oil and gas in the Middle East. These two geological reasons support the fact that coal reserves have potential to be the dominant fossil fuel in the future.

Region	**Fossil fuel reserve (giga tonnes of oil equivalent)**				**Fossil fuel reserve (%)**			
	Oil	**Coal**	**Gas**	**Sum**	**Oil**	**Coal**	**Gas**	**Sum**
North America	8	170	7	185	0.86	18.20	0.75	19.81
South America	15	13	6	34	1.61	1.39	0.64	3.64
Europe	2	40	5	47	0.21	4.28	0.54	5.03
Africa	16	34	13	63	1.71	3.64	1.39	6.75
Russia	18	152	52	222	1.93	16.27	5.57	23.77
Middle East	101	0	66	167	10.81	0.00	7.07	17.88
India	1	62	1	64	0.11	6.64	0.11	6.85
China	2	76	2	80	0.21	8.14	0.21	8.57
Australia and East Asia	2	60	10	72	0.21	6.42	1.07	7.71
Total	165	607	162	934	17.67	64.99	17.34	100.00

[*Source*: WCI (2007) and BP (2006)]

Table 1. Location of the world's main fossil fuel reserves in 2006

Fossil fuel reserve trends tend to mainly depend on two important parameters: consumption and price. The Energy Information Administration (EIA) has projected that energy consumption will increase at an average rate of 1.1% per annum, from 500 quadrillion Btu in 2006 to 701.6 quadrillion Btu in 2030. Currently, the growth in world energy consumption is approximately 2% per annum. "In terms of global consumption, crude oil remains the most important primary fuel accounting for 36.4% of the world's primary energy consumption (without biomass)". The International Energy Agency (IEA) claims oil demand as the single largest consumable fossil fuel in the global energy market will fall from 35% to 32% by 2030. Coal is the second largest consumable fossil fuel relative to the three main fossil fuels; in part largely due to consumption over the past couple of years. According to WEO 2007, "coal is seen to have the biggest increase in demand in absolute terms, jumping by 73% between 2005 and 2030". "Coal accounted for about 28% of global primary energy consumption in 2005; surpassed only by crude oil" (BGR, 2007). Reserves of gas in comparison to oil and coal will moderately increase for the next two decades, from 21% to 22%. Although other energy resources are expanding in the world, the rate of fossil fuel consumption for energy will also continue to increase through to 2030.

The next important issue after global consumption of fossil fuels is fossil fuel price movement. Proven fossil fuel reserves will fluctuate according to economic conditions, especially fossil fuel prices. In other words, proven reserves will shrink when prices are too low for fossil fuels to be recovered economically and expand when prices deem fossil fuels economically recoverable. In addition, the trend of fossil fuel prices significantly affects fossil fuel consumption. On the other hand, fossil fuel price fluctuations affect other variables such as international inflation, global GDP growth, etc. Consequently, the size of fossil fuel reserves depends on their prices.

The oil price is currently very high at around $140 per barrel in nominal terms. This is much higher than after several other oil price crises, such as the Iran/Iraq war, Gulf war and 9/11 as per WTRG, 2008. According to OPEC (2007), OPEC benchmark crude price is assumed to remain in the $50 to $60 per barrel range in nominal terms for much of the projected period and rising further in the longer term with inflation. Therefore, the oil price at the moment is much higher than the OPEC prediction. Moreover, WEC (2007) forecast the oil price based on the assumption that the average crude oil price will fall back from recent highs of over $75 per barrel to around $60 (in year 2006 dollars) by 2015 and then recover slowly, reaching $62 (or $108 in nominal terms) by 2030. Coal prices have had less fluctuation in comparison to oil in the last 50 years. The coal market depicts relatively constant coal prices in historical data. WEC (2007) assumes that this trend will remain flat until the middle of the next decade, then increase very slowly, reaching just over $60 per tonne by 2030. Gas prices have generally followed the increase in oil prices since 2003, typically with a 1 year lag. Annual Energy Outlook 2007 predicted that the average transmission and distribution margin for delivered gas is projected to change from $2.38 per thousand cubic feet in 2006 to between $2.07 and $2.44 per thousand cubic feet in 2030 (2005 dollars). As a result, forecasting fossil fuel prices are uncertain and unpredictable.

2.2 Fossil fuel reserve versus consumption

The trends of fossil fuel reserves versus consumption are discussed. As can be seen from Fig.1, the trend of oil and gas reserves with their consumption increased. This means that reserve and consumption for oil and gas over the last 26 years have an unusual positive correlation.

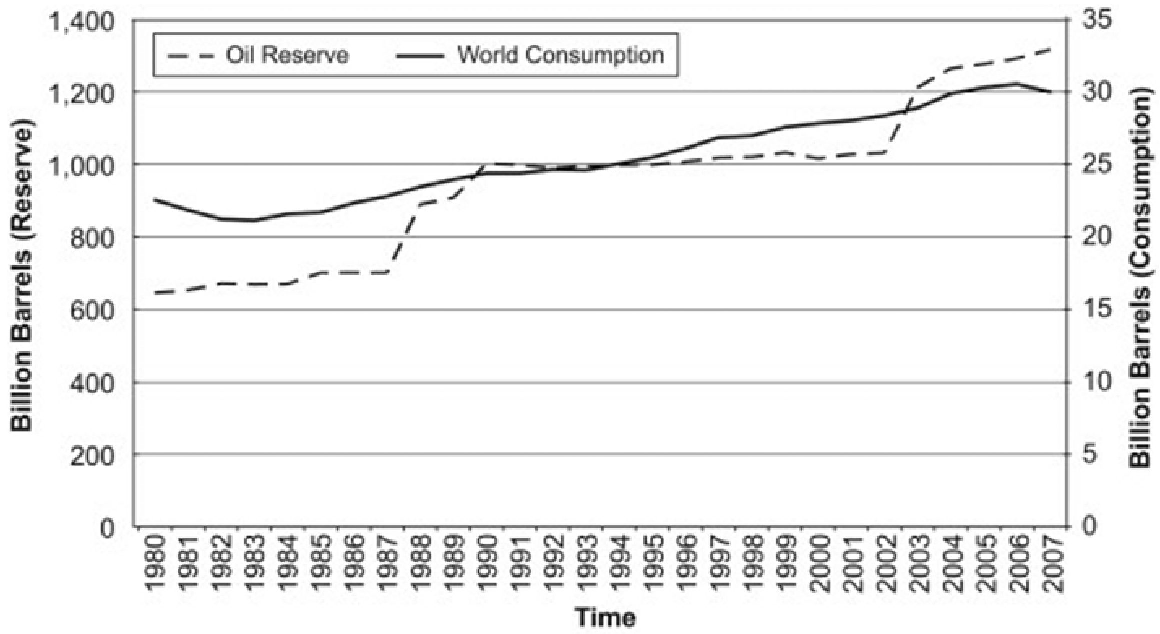


Fig. 1. Trends of world crude oil proven reserves and oil consumption from 1980 to 2007. [*Source*: EIA and BP]

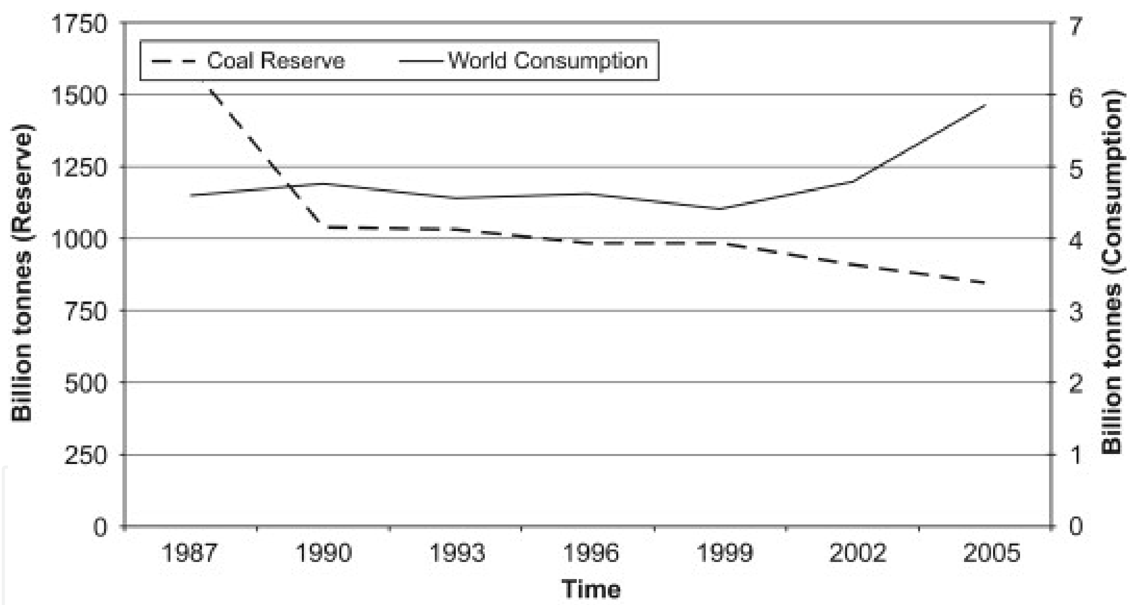


Fig. 2. Trends of world coal proven reserves and coal consumption from 1987 to 2005. [*Source*: EIA and BP]

Fig. 2 shows reserve versus consumption of coal. This graph shows a negative correlation between coal reserve and consumption. In spite of the fact that the data for coal were less available and more volatile in comparison to oil and gas, the relation between coal reserve and coal consumption is still negative and significant. According to *Shihab-Eldin (2004*), the increase in fossil fuel resources is due to the availability of improved data, as well as technological improvements. Consequently, the reserves of oil and gas have not shown any decreasing trend during the last couple of decades and predictions that they were about to run out are not substantiated *for the last 26 years (1980 to 2007) as seen from Fig. 1 and Fig. 3*.

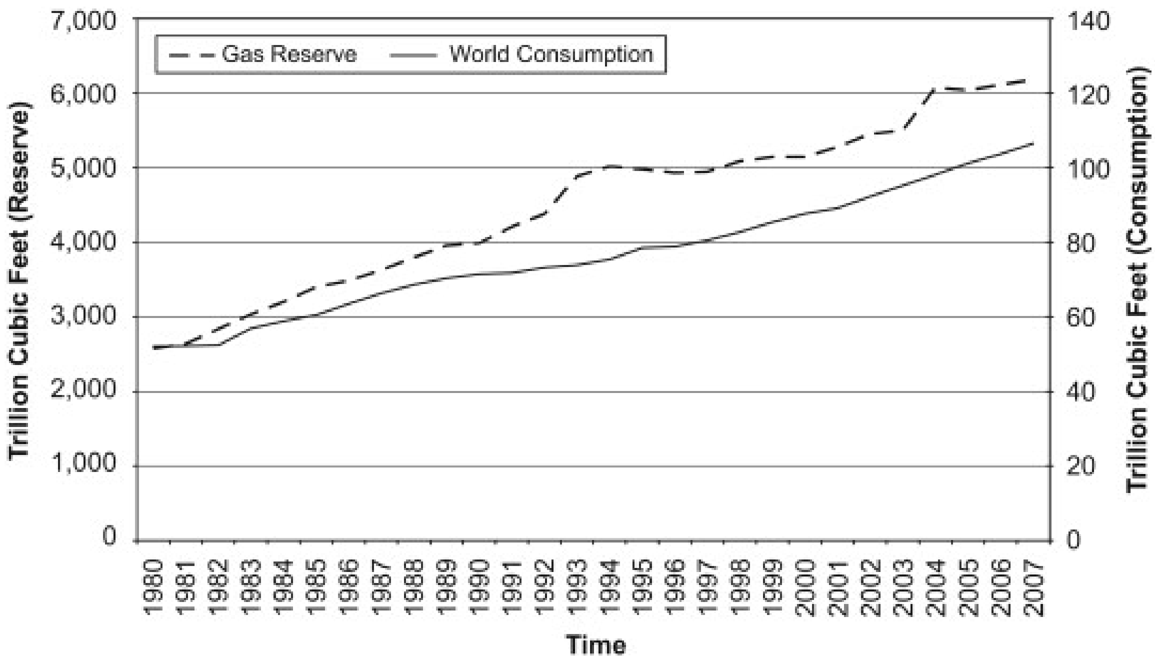


Fig. 3. Trends of world natural gas proven reserves and gas consumption from 1980 to 2007. [*Source*: EIA and BP]

2.3 Fossil fuel reserves versus depletion time

Most researchers estimate reserve depletion time by assuming constant production rates. For example, WEO 2006 estimated a ratio for oil of between 39 and 43 years, 164 year for coal and 64 years for gas. *Lior* (*2008*) assumed constant fossil fuel production rates and then estimated the ratio of production to reserves to be approximately 40, 60 and 150 for oil, gas and coal, respectively. As can be seen, none of the research modified the rate of production or consumption of fossil fuel to calculate the ratio of consumption to reserves. Consequently, the new model added this assumption and adjusted new formula to calculate fossil fuel reserve depletion time.

Model	Ratio of consumption to reserves			Klass model			New model		
	Oil	Coal	Gas	Oil	Coal	Gas	Oil	Coal	Gas
Year	40	200	70	34	106	36	35	107	37

[*Source*: EIA and BP, and computed]

Table 2. Fossil fuel reserves depletion times

Table 2 illustrates the time that fossil fuels will be depleted using the Klass model and new model. As can be seen in this table, the Klass model for oil, coal and gas depletion times is calculated to be about 34, 106 and 36 years, respectively, compared to 35, 107 and 37 in the new model. Ultimately, the reserve of coal using either approach still has a longer availability than oil and gas. This means that the coal reserves will be available until at least 2112 at this rate, and it will be the single fossil fuel in the world as indicated in Table 2. Fossil fuel reserves depletion times after 2042.

The second method tries to calculate the time that fossil fuels will be depleted by computing ratio of consumption to reserves. Thus, the average ratios of world consumption to reserves for oil, coal and gas can be computed from Fig. 1, Fig. 2 and Fig. 3.The graphs Fig.4, shows the trend of ratio of world consumption to reserves for oil, coal and gas from 1980 to 2006.

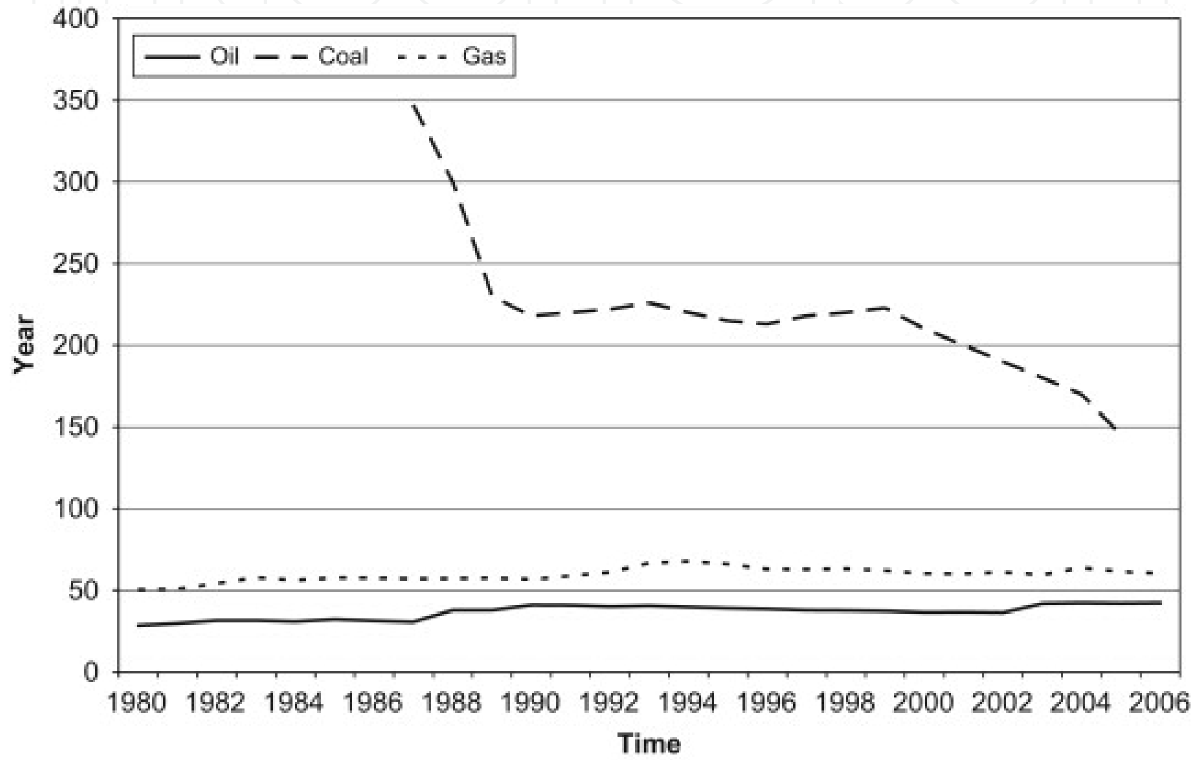


Fig. 4. The ratios of world consumption to reserves for oil, coal and gas from 1980 to 2006.

As can be seen in this figure these ratios for oil and gas were constant, around 40 and 60 years, respectively. This means that during the last 26 years, the reserves of oil and gas have not shown any decreasing trend during the last couple of decades and predictions that they were about to run out are not substantiated for the last 26 years (1980 to 2007) as seen from Fig. *1 and Fig. 3*. This means that if the world continues to consume oil, coal and gas at 2006 rates, their reserves will last a further 40, 200 and 70 years, respectively.

3. Nature of global warming and climate change

Global warming and climate change refer to an increase in average global temperatures. Natural events and human activities are believed to be contributing to an increase in average global temperatures. This is caused primarily by increases in "greenhouse" gases such as Carbon Dioxide (CO_2).A warming planet thus leads to a change in climate which can affect weather in various ways, as shown below.

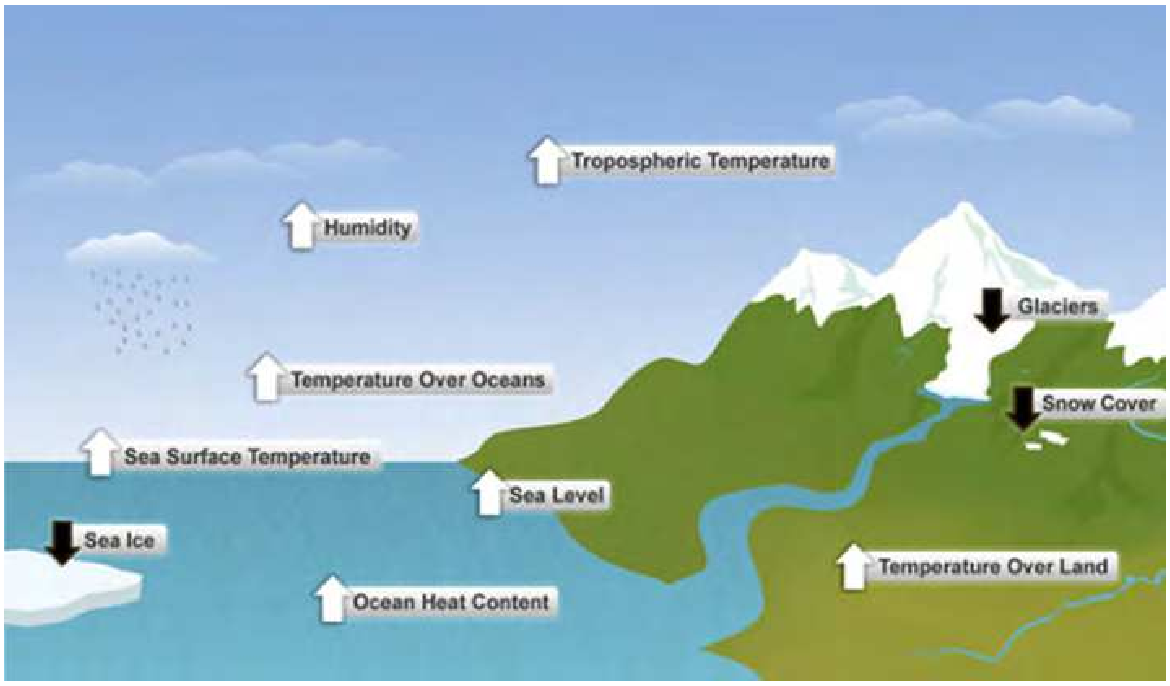


Fig. 5. Ten indicators for a warming world, Past Decade Warmest on Record According to Scientists in 48 Countries, NOAA, July 28, 2010

For decades, scientists and environmentalists have warned that the way we are using Earth's resources is not sustainable. Alternative technologies have been called for repeatedly, seemingly upon deaf ears (or, cynically, upon those who don't want to make substantial changes as it challenge their bottom line and takes away from their current profits).

Global warming in today's scenario is threat to the survival of mankind. In 1956, an US based Chief consultant and oil geologist *Marion King Hubert, (1956)* predicted that if oil is consumed with high rate, US oil production may peak in 1970 and thereafter it will decline. He also described that other countries may attain peak oil day within 20-30 years and many more may suffer with oil crises within 40 years, when oil wells are going to dry. He illustrated the projection with a bell shaped *Hubert Curve* based on the availability and its consumptions of the fossil fuel. Large fields are discovered first, small ones later. After exploration and initial growth in output, production plateaus and eventually declines to zero.

In India, vehicular pollution is estimated to have increased eight times over the last two decades. This source alone is estimated to contribute about 70 per cent to the total air pollution. With 243.3 million tons of carbon released from the consumption and combustion of fossil fuels in 1999, India is ranked fifth in the world behind the U.S., China, Russia and Japan. India's contribution to world carbon emissions is expected to increase in the coming years due to the rapid pace of urbanization, shift from non-commercial to commercial fuels, increased vehicular usage and continued use of older and more inefficient coal-fired and fuel power-plants (*Singh, BR, et al., 2010*).

Thus, peak oil year may be the turning point for mankind which in turn led to the end of 100 year of easy growth and may end up a better world, if self-sufficiently and sustainability of energy is not maintained on priority. Although the worldwide efforts are being made to explore non-conventional energy resources such as: solar energy, wind energy, bio-mass and bio-gas, hydrogen, bio-diesel which may help for the sustainable fossil fuel reserves and reduce the tail pipe emission and other pollutants like: $CO_{2,}$ NO_X etc., but special emphasis should also be laid upon to the storage of energy such as compressed air stored from solar, wind and or other resources like: climatic / disaster energy to be tapped down to maintain energy sustainability of 21st century which may also lead to environmentally and ecologically better future.

3.1 Effect of global warming

The various effects of climate change pose risks that increase with global warming (i.e., increases in the Earth's global mean temperature). The IPCC (*2001d and 2007d*) has organized many of these risks into five "reasons for concern:

- Threats to endangered species and unique systems,
- Damages from extreme climate events,
- Effects that fall most heavily on developing countries and
- The poor within countries, global aggregate impacts (i.e., various measurements of total social, economic and ecological impacts), and large-scale high-impact events.

The effects, or impacts, of climate change may be physical, ecological, social or economic. Evidence of observed climate change includes the instrumental temperature record, rising sea levels, and decreased snow cover in the Northern Hemisphere. According to the Intergovernmental Panel on Climate Change (*IPCC, 2007a:10*), "[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. United Nations Framework Convention on Climate Change has agreed to implement policies designed to reduce their emissions of greenhouse gases.

3.2 Effect of climate change

The phrase climate change is used to describe a change in the climate, measured in terms of its statistical properties, e.g., the global mean surface temperature. In this context, climate is taken to mean the average weather. Climate can change over period of time ranging from months to thousands or millions of years. The classical time period is 30 years, as defined by the World Meteorological Organization. The climate change may be due to natural causes, e.g., changes in the sun's output, or due to human activities, e.g., changing the composition of the atmosphere. Any human-induced changes in climate will occur against the background of natural climatic variations.

The most general definition of *climate change* is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause, *whereas* Global warming" refers to the change in the Earth's global average surface temperature. Measurements show a global temperature increase of 1.4 °F (0.78 °C) between the years 1900 and 2005. Global warming is closely associated with a broad spectrum of other climate changes, such as:

- Increases in the frequency of intense rainfall,
- Decreases in snow cover and sea ice,
- More frequent and intense heat waves,
- Rising sea levels, and
- Widespread ocean acidification.

3.2.1 Impacts of climate change

According to different levels of future global warming, impacts of climate has been used in the IPCC's Assessment Reports on climate change (*Schneider DH, et al., 2007*). The instrumental temperature record shows global warming of around 0.6 °C over the entire 20th century (*IPCC 2007d.1*). The future level of global warming is uncertain, but a wide range of estimates (projections) have been made (*Fisher, BS et al., 2007*). The IPCC's "SRES" scenarios have been frequently used to make projections of future climate change (*Karl, 2009*). Climate models using the six SRES "marker" scenarios suggest future warming of 1.1 to 6.4 °C by the end of the 21st century (above average global temperatures over the 1980 to 1999 time period) (*IPCC 2007d.3*). The projected rate of warming under these scenarios would very likely be without precedent during at least the last 10,000 years (*IPCC 2001-SPM*). The most recent warm period comparable to these projections was the mid-Pliocene, around 3 million years ago (*Stern N., 2008*). At that time, models suggest that mean global temperatures were about 2–3 °C warmer than pre-industrial temperatures (*Jansen E., et al., 2007*).

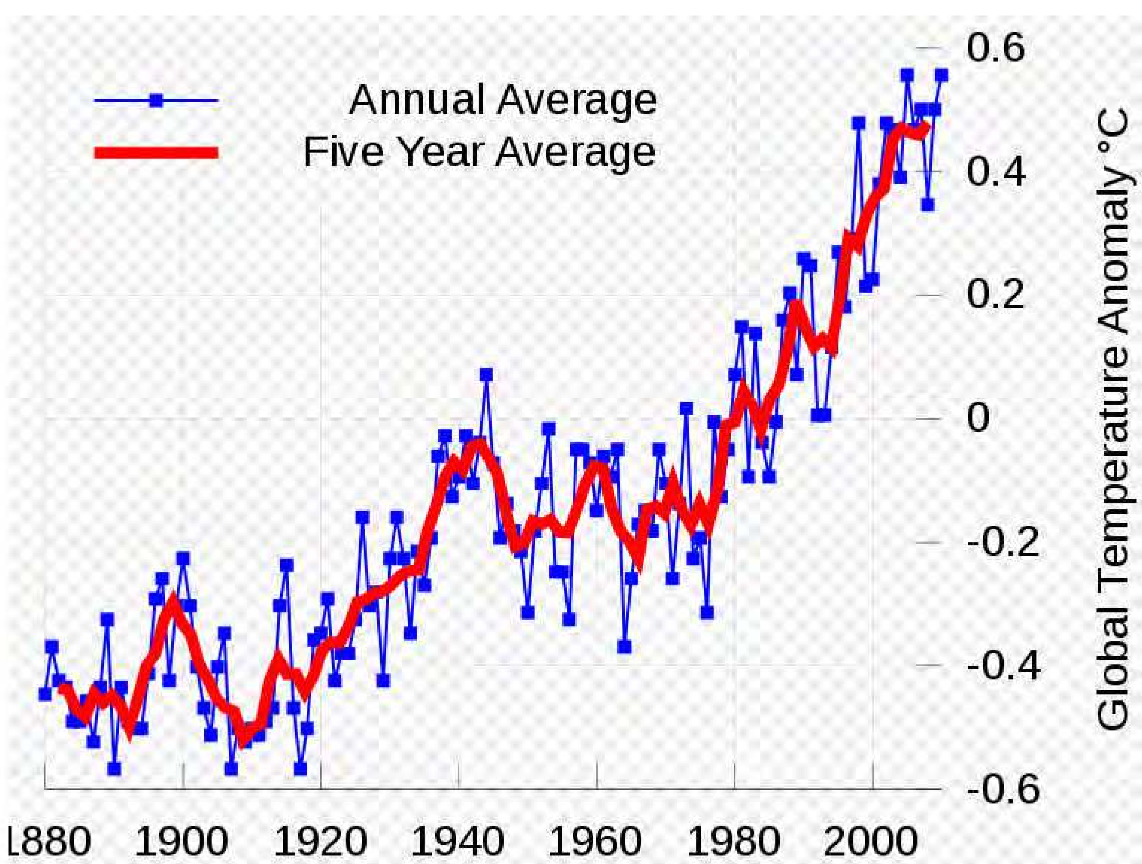


Fig. 6a. Global mean surface temperature difference from the average for 1880–2009

The most recent report IPCC projected that during the 21st century the global surface temperature is likely to rise a further1.1 to 2.9 °C (2 to 5.2 °F) for the lowest emissions scenario used in the report and 2.4 to 6.4 °C (4.3 to 11.5 °F) for the highest

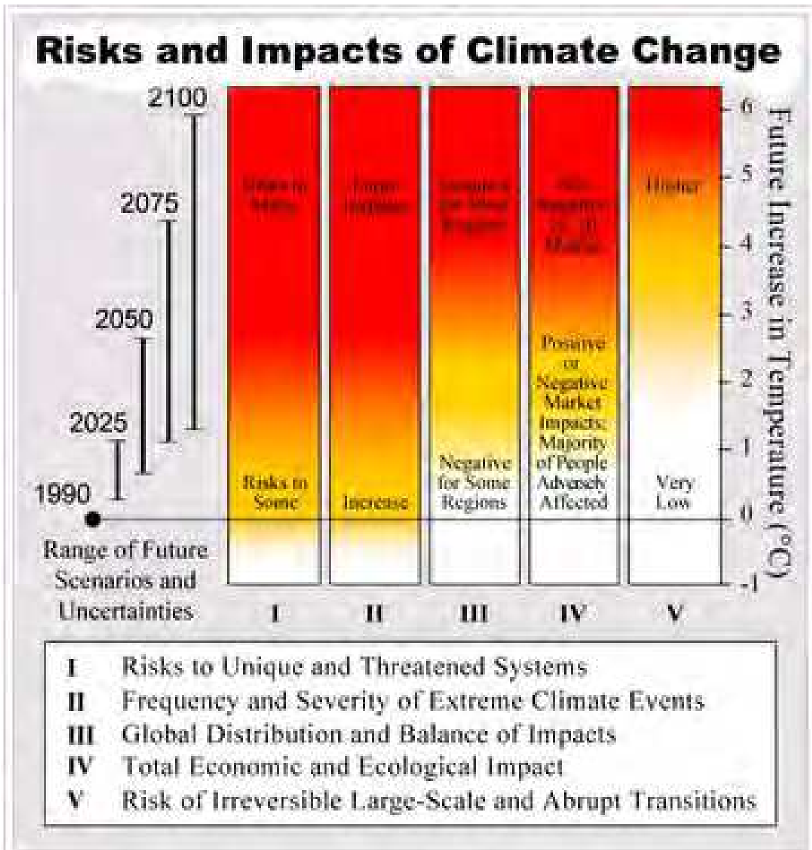


Fig. 6b. Projected Global Temperature Rise 1.1 to 6.4 °C during 21st century

3.2.2 Physical impacts of climate change

Working Group I's contribution to the IPCC Fourth Assessment Report, published in 2007, concluded that warming of the climate system was "unequivocal" (*Solomon S, 2007a*). This was based on the consistency of evidence across a range of observed changes, including increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level(*Solomon S, 2007b*).

Human activities have contributed to a number of the observed changes in climate (*Hegerl GC, et. al., 2007*). This contribution has principally been through the burning of fossil fuels, which has led to an increase in the concentration of GHGs in the atmosphere. This increase in GHG concentrations has caused a radiative forcing of the climate in the direction of warming. Human-induced forcing of the climate has likely to contributed to a number of observed changes, including sea level rise, changes in climate extremes (such as warm and cold days), declines in Arctic sea ice extent, and to glacier retreat.

Human-induced warming could potentially lead to some impacts that are abrupt or irreversible. The probability of warming having unforeseen consequences increases with the rate, magnitude, and duration of climate change.

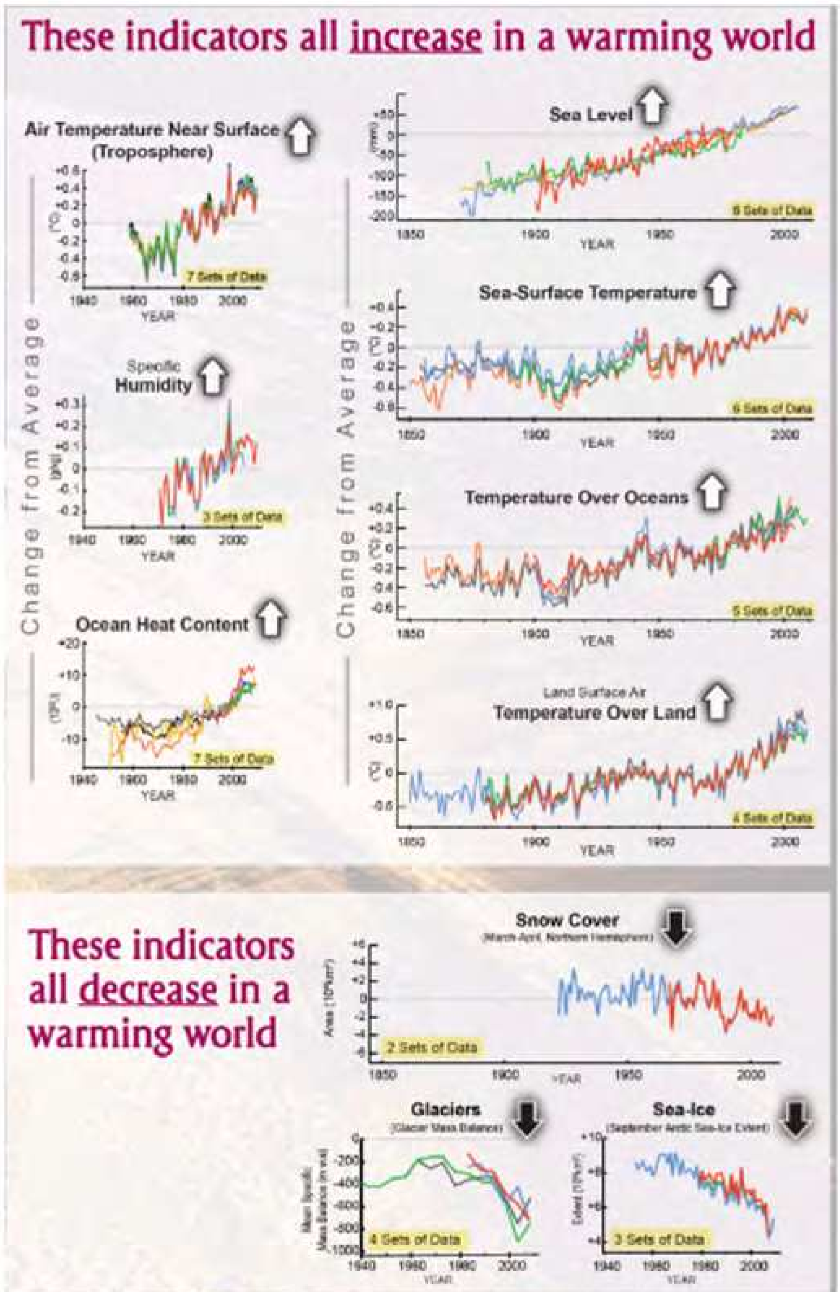


Fig. 7. Key climate indicators that show global warming

3.2.3 Effects on weather

Observations show that there have been changes in weather (*Le Treut H, et. al., 2007*). As climate changes, the probabilities of certain types of weather events are affected. Changes have been observed in the amount, intensity, frequency, and type of precipitation. Widespread increases in heavy precipitation have occurred, even in places where total rain amounts have decreased. IPCC (2007d) concluded that human influences had, more likely than not (greater than 50% probability, based on expert judgement), contributed to an increase in the frequency of heavy precipitation events. Projections of future changes in precipitation show overall increase in the global average, but with substantial shifts in where and how precipitation falls. Climate models tend to project increasing precipitation at high latitudes and in the tropics (e.g., the south-east monsoon region and over the tropical Pacific) and decreasing precipitation in the sub-tropics (e.g., over much of North Africa and the northern Sahara).

Evidence suggests that, since the 1970s, there have been substantial increases in the intensity and duration of tropical storms and hurricanes. Models project a general tendency for more intense but fewer storms outside the tropics.

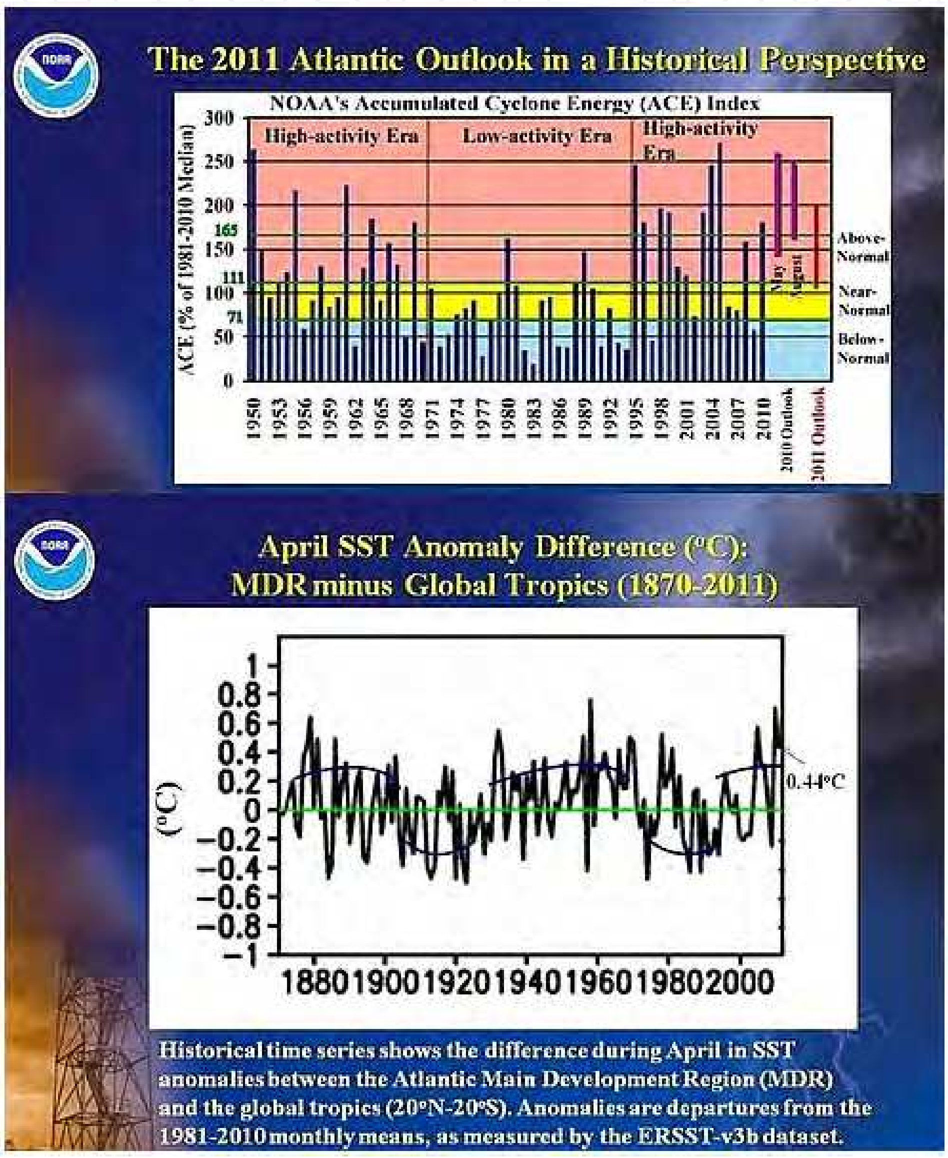


Fig. 8. Accumulated cyclone energy in the Atlantic Ocean and the sea surface temperature difference which influences such, measured by the U.S. NOAA.

3.2.4 Extreme weather, tropical cyclone, and list of atlantic hurricane records

Since the late 20th century, changes have been observed in the trends of some extreme weather and climate events, e.g., heat waves. Human activities have, with varying degrees of confidence, contributed to some of these observed trends. Projections for the 21st century suggest continuing changes in trends for some extreme events. Solomon *et al.* (2007), for example, projected the following likely (greater than 66% probability, based on expert judgment) changes:

- Increase in the areas affected by drought;
- Increased tropical cyclone activity and
- Increased incidence of extreme high sea level (excluding tsunamis).

Projected changes in extreme events will have predominantly adverse impacts on ecosystems and human society.

3.2.5 Glacier retreat since 1850 and disappearance

IPCC (2007a:5) found that, on average, mountain glaciers and snow cover had decreased in both the northern and southern hemispheres.

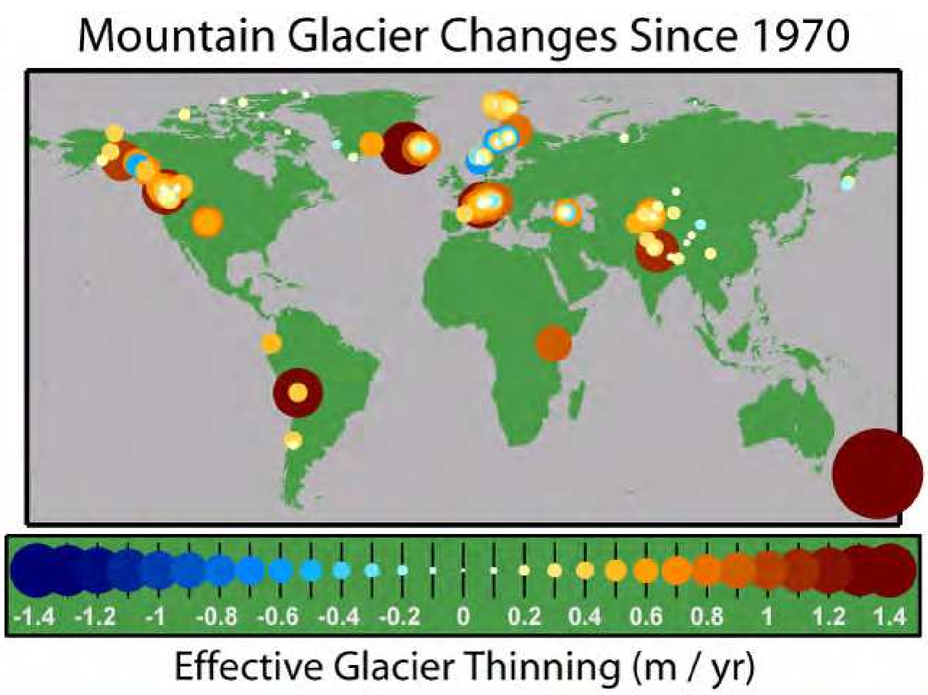


Fig. 9. A map of the change in thickness of mountain glaciers since 1970 (Thinning in orange and red, thickening in blue).

This widespread decrease in glaciers and ice caps had contributed to observed sea level rise. With very high or high confidence, *IPCC (2007d: 11)* made a number of projections relating to future changes in glaciers:

- Mountainous areas in Europe will face glacier retreat
- In Polar Regions, there will be reductions in glacier extent and the thickness of glaciers.
- More than one-sixth of the world's populations are supplied by melt-water from major mountain ranges. Changes in glaciers and snow cover are expected to reduce water availability for these populations.
- In Latin America, changes in precipitation patterns and the disappearance of glaciers will significantly affect water availability for human consumption, agriculture, and energy production.

3.2.6 Role of the oceans in global warming

The oceans serve as a sink for carbon dioxide, taking up much that would otherwise remain in the atmosphere, but increased levels of CO_2 have led to ocean acidification. Furthermore, as the temperature of the oceans increases, their absorptivity for excess CO_2 decreases. The oceans have also acted as a sink in absorbing extra heat from the atmosphere. This extra heat has been added to the climate system due to the build-up of GHGs. More than 90 percent of warming that occurred over 1960–2009 is estimated to have gone into the oceans.

Global warming is projected to have a number of effects on the oceans. Ongoing effects include rising sea levels due to thermal expansion and melting of glaciers and ice sheets, and warming of the ocean surface, leading to increased temperature stratification. Other possible effects include large-scale changes in ocean circulation.

a. *Number of tropical storms and hurricanes per season*: This bar chart shows the number of named storms and hurricanes per year from 1893-2010.
- Costliest tropical cyclone: Hurricane Katrina - 2005 - $81.2 billion in damages.
- Smallest tropical cyclone on record: Marco - 2008 - gale force winds extended 10 mi (20 km) from storm center (previous record: Cyclone Tracy 1974 - 30 mi (50 km))

b. *Ocean Acidification*: About one-third of the carbon dioxide emitted by human activity has already been taken up by the oceans. As carbon dioxide dissolves in sea water, carbonic acid is formed, which has the effect of acidifying the ocean, measured as a change in pH. The uptake of human carbon emissions since the year 1750 has led to an average decrease in pH of 0.1 units (*IPCC 2007d. "3.3.4 Ocean acidification*). Projections using the SRES emissions scenarios suggest a further reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century.

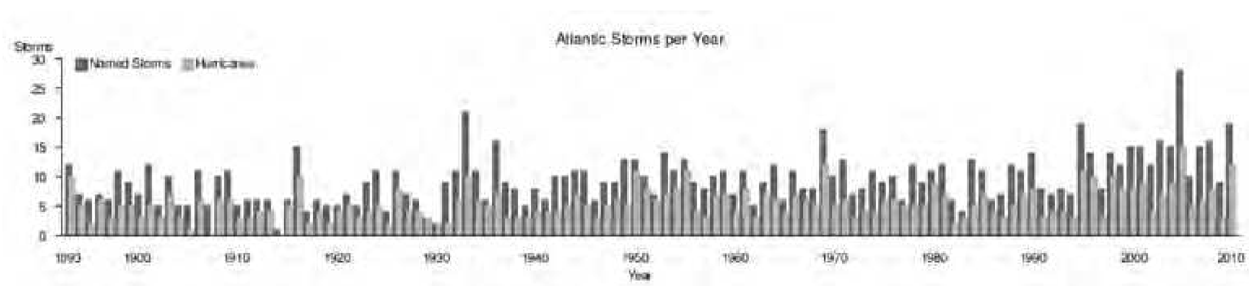


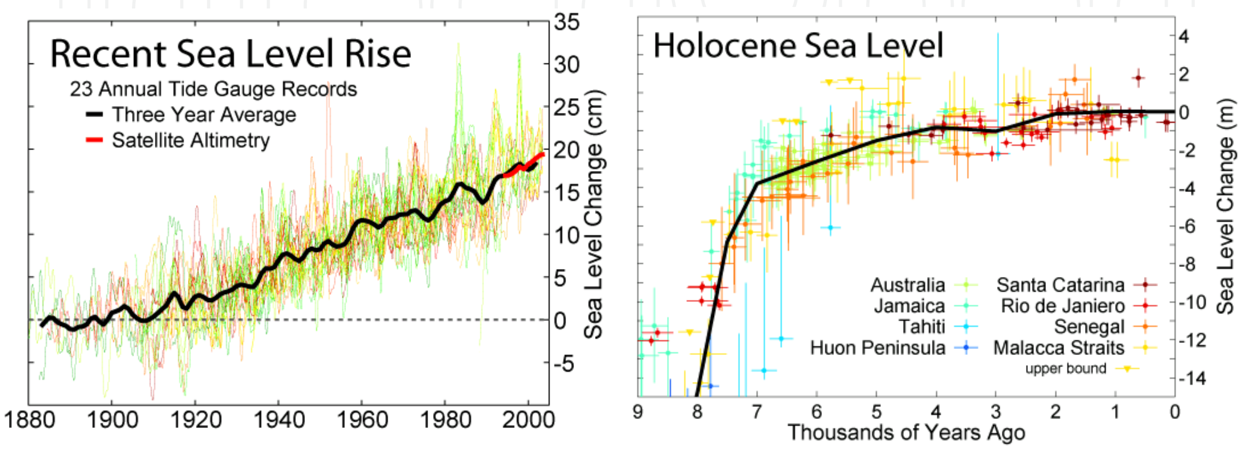
Fig. 10. Worldwide cyclone records set by Atlantic storms

The effects of ocean acidification on the marine biosphere have yet to be documented. Laboratory experiments suggest beneficial effects for a few species, with potentially highly detrimental effects for a substantial number of species. With medium confidence, Fischlin *et al.* (2007) projected that future ocean acidification and climate change would impair a wide range of plank tonic and shallow benthic marine organisms that use aragonite to make their shells or skeletons, such as corals and marine snails (pteropods), with significant impacts particularly in the Southern Ocean.

c. *Oxygen Depletion*: The amount of oxygen dissolved in the oceans may decline, with adverse consequences for ocean life (*Crowley TJ, 1988; Shaffer G, et al., 2009*).

d. *Sea level rise*: Sea level has been rising 0.2 cm/yr, based on measurements of sea level rise from 23 long tide gauge records in geologically stable environments. Sea level was projected to rise by 18 to 59 cm (7.1 to 23.2 in) for the time period 2090–99. This projection is with the increase in level relative to average global sea level over the 1980–99 periods (*Bindoff, NL, et al., 2007*).

The IPCC (2007d, p. 5) reported that between 1961 and 2003, global average sea level rose at an average rate of 1.8 mm per year (mm/yr), with an uncertainty range of 1.3–2.3 mm/yr. Between 1993 and 2003, the rate increased above the previous period to 3.1 mm/yr (uncertainty range of 2.4–3.8 mm/yr).



(a) (b)

Fig. 11. (a) Current sea level rise and (b) Sea level rise during the Holocene.

A range of projections suggested possible sea level rise by the end of the 21st century of between 0.56 and 2 m. These projections are based on the same measurement range, with the increase in sea level by 2090-99 measured against average global sea level over the 1980–99 time periods.

e. *Ocean temperature rise*: From 1961 to 2003, the global ocean temperature has risen by 0.10 °C from the surface to a depth of 700 m. There is variability both year-to-year and over longer time scales, with global ocean heat content observations showing high rates of warming for 1991–2003, but some cooling from 2003 to 2007 (*Bindoff, NL, 2011*). The temperature of the Antarctic Southern Ocean rose by 0.17 °C (0.31 °F) between the 1950s and the 1980s, nearly twice the rate for the world's oceans as a whole (*Gille, Sarah T, 2002*). As well as having effects on ecosystems (e.g. by melting sea ice, affecting algae that grow on its underside), warming reduces the ocean's ability to absorb CO_2.

f. *Regional effects of global warming*: Some are the results of a generalised global change, such as rising temperature, resulting in local effects, such as melting ice. In other cases, a change may be related to a change in a particular ocean current or weather system. In such cases, the regional effect may be disproportionate and will not necessarily follow the global trend.

There are three major ways in which global warming will make changes to regional climate: melting or forming ice, changing the hydrological cycle (of evaporation and precipitation) and changing currents in the oceans and air flows in the atmosphere. The coast can also be considered a region, and will suffer severe impacts from sea level rise.

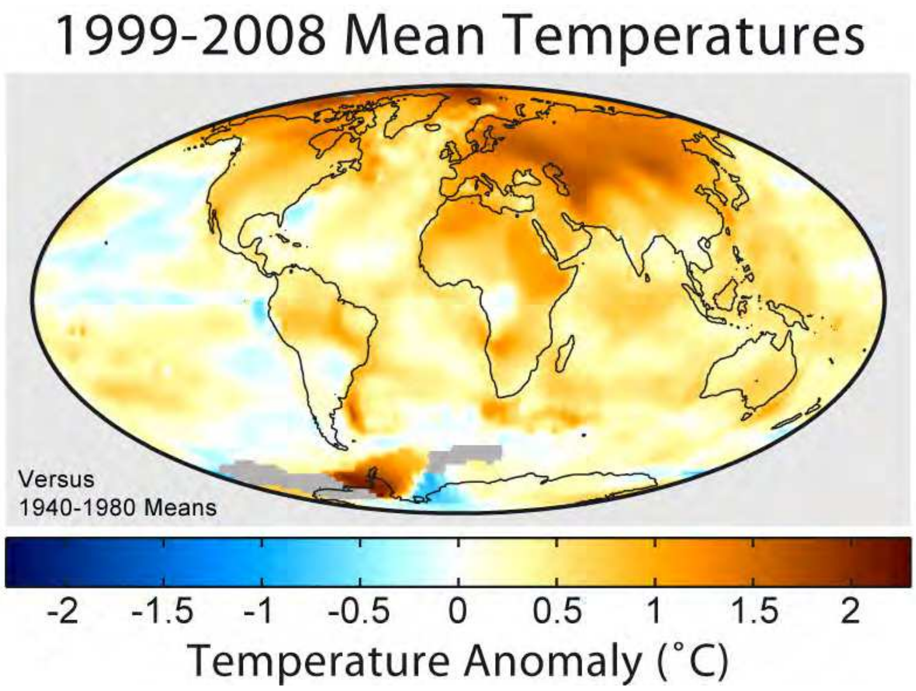


Fig. 12. Mean surface temperature change for 1999–2008 relative to the average temperatures from 1940 to 1980

- *Social systems*: The impacts of climate change can be thought of in terms of sensitivity and vulnerability. "Sensitivity" is the degree to which a particular system or sector might be affected, positively or negatively, by climate change and/or climate variability. "Vulnerability" is the degree to which a particular system or sector might be adversely affected by climate change.
  The sensitivity of human society to climate change varies. Sectors sensitive to climate change include water resources, coastal zones, human settlements, and human health. Industries sensitive to climate change include agriculture, fisheries, forestry, energy, construction, insurance, financial services, tourism, and recreation.
- *Food supply*: Climate change will impact agriculture and food production around the world due to: the effects of elevated CO_2 in the atmosphere, higher temperatures, altered precipitation and transpiration regimes, increased frequency of extreme events, and modified weed, pest, and pathogen pressure (Easterling *et al.*, 2007). In general, low-latitude areas are at most risk of having decreased crop yields (Schneider *et al.*, 2007).
  So far, the effects of regional climate change on agriculture have been relatively limited. Changes in crop phenology provide important evidence of the response to recent regional climate change. Phenology is the study of natural phenomena that recur periodically, and how these phenomena relate to climate and seasonal changes. A significant advance in phenology has been observed for agriculture and forestry in large parts of the Northern Hemisphere.
- *Health*: Human beings are exposed to climate change through changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in water, air and food quality and changes in ecosystems, agriculture, industry and settlements and the economy (Confalonieri *et al.*, 2007a). According to a literature assessment, the effects of climate change to date have been small, but are projected to progressively increase in all countries and regions.

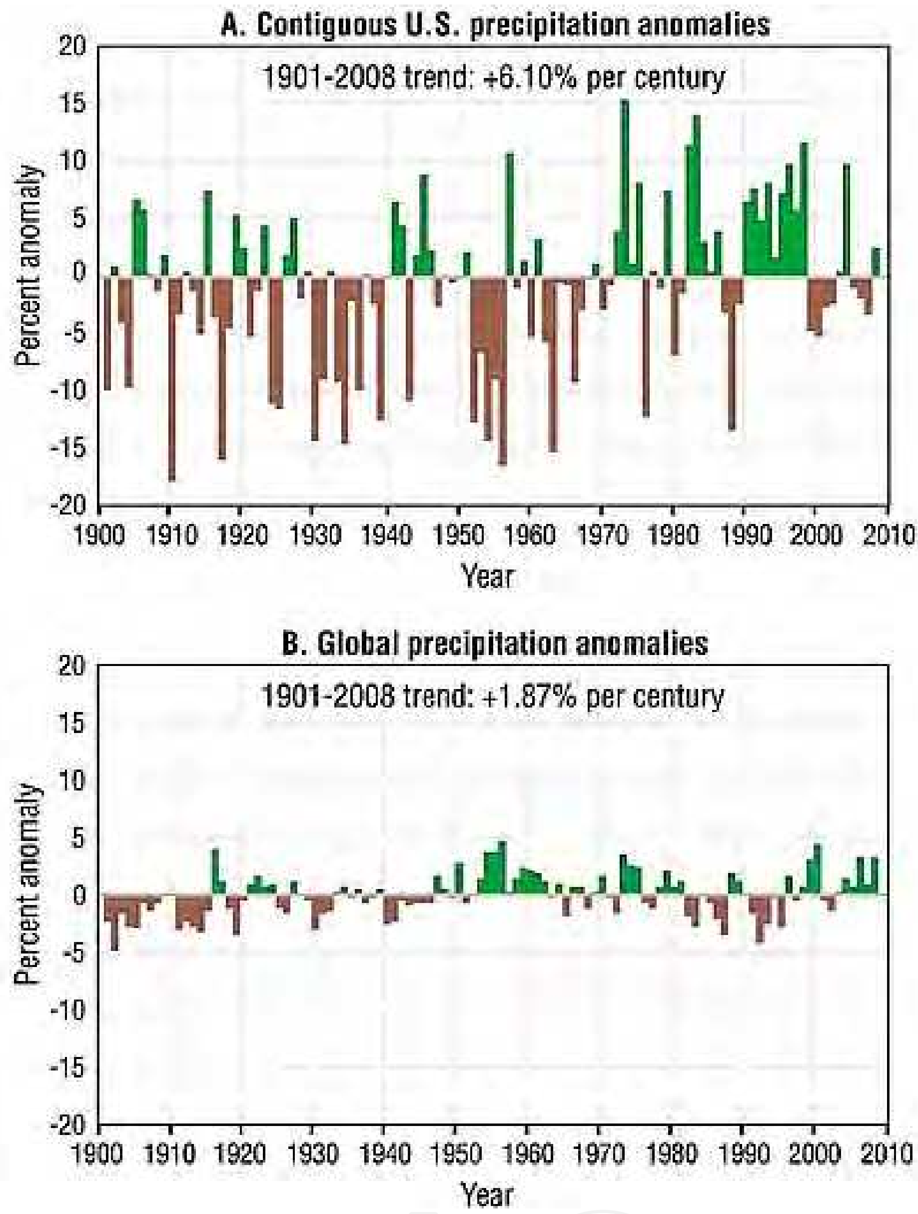


Fig. 13. Precipitation during the 20th century and up through 2008 during global warming, the NOAA estimating an observed trend over that period of 1.87% global precipitation increase per century.

A study by the World Health Organization (*WHO, 2009*) estimated the effect of climate change on human health. Not all of the effects of climate change were included in their estimates, for example, the effects of more frequent and extreme storms were excluded. Climate change was estimated to have been responsible for 3% of diarrhoea, 3% of malaria, and 3.8% of dengue fever deaths worldwide in 2004. Total attributable mortality was about 0.2% of deaths in 2004; of these, 85% were child deaths.

- *Projections*: With high confidence, IPCC (2007d:48) projected that climate change would bring some benefits in temperate areas, such as fewer deaths from cold exposure, and some mixed effects such as changes in range and transmission potential of malaria in Africa. Benefits were projected to be outweighed by negative health effects of rising temperatures, especially in developing countries.

- *Extreme events*: With high confidence, Confalonieri *et al.* (2007b) projected that climate change would increase the number of people suffering from death, disease and injury from heatwaves, floods, storms, fires and droughts.
- *Floods and weather disasters*: Floods are low-probability, high-impact events that can overwhelm physical infrastructure and human communities (Confalonieri *et al.*, 2007c). Major storm and flood disasters have occurred in the last two decades. The impacts of weather disasters are considerable and unequally distributed. For example, natural disasters have been shown to result in increased domestic violence against - and post-traumatic stress disorders in – women. In terms of deaths and populations affected, floods and tropical cyclones have the greatest impact in South Asia and Latin America. Vulnerability to weather disasters depends on the attributes of the person at risk, including where they live and their age, as well as other social and environmental factors. High-density populations in low-lying coastal regions experience a high health burden from weather disasters.
- *Heatwaves*: Hot days, hot nights and heatwaves have become more frequent (*Confalonieri et al., 2007d*). Heatwaves are associated with marked short-term increases in mortality. For example, in August 2003, a heat wave in Europe resulted in excess mortality in the range of 35,000 total deaths.
  Heat-related morbidity and mortality is projected to increase (Confalonieri *et al.*, 2007*e*). The health burden could be relatively small for moderate heatwaves in temperate regions, because deaths occur primarily in susceptible persons.
- *Drought*: The effects of drought on health include deaths, malnutrition, infectious diseases and respiratory diseases. Countries within the "Meningitis Belt" in semi-arid sub-Saharan Africa experience the highest endemicity and epidemic frequency of meningococcal meningitis in Africa, although other areas in the Rift Valley, the Great Lakes, and southern Africa are also affected (*Confalonieri et al., 2007f*). The spatial distribution, intensity, and seasonality of meningococcal (epidemic) meningitis appear to be strongly linked to climate and environmental factors, particularly drought. The cause of this link is not fully understood.
- *Fires*: In some regions, changes in temperature and precipitation are projected to increase the frequency and severity of fire events (*Confalonieri et al., 2007g*). Forest and bush fires cause burns, damage from smoke inhalation and other injuries.
- *Infectious disease vectors*: With high confidence, *Confalonieri et al. (2007h)* projected that climate change would continue to change the range of some infectious disease vectors such as: Dengue, Malaria, Diarrhoeal diseases etc. Vector-borne diseases, (VBD) are infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, triatomine bugs, sandflies, and blackflies. There is some evidence of climate-change-related shifts in the distribution of tick vectors of disease, of some (non-malarial) mosquito vectors in Europe and North America. Climate change has also been implicated in changes in the breeding and migration dates of several bird species. Several species of wild bird can act as carriers of human pathogens as well as of vectors of infectious agents.
- *Ground-level ozone*: With high confidence, *Confalonieri et al. (2007i)* projected that climate change would increase cardio-respiratory morbidity and mortality associated with ground-level ozone. Ground-level ozone is both naturally occurring and is the primary constituent of urban smog (*Confalonieri et al., 2007j*). Ozone in smog is formed through

chemical reactions involving nitrogen oxides and other compounds. The reaction is a photochemical reaction, meaning that it involves electromagnetic radiation, and occurs in the presence of bright sunshine and high temperatures. Exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis and other respiratory diseases, and with premature mortality.
Background levels of ground-level ozone have risen since pre-industrial times because of increasing emissions of methane, carbon monoxide and nitrogen oxides (*Confalonieri et al., 2007k*). This trend is expected to continue into the mid-21st century.

- *Cold-waves*: Cold-waves continue to be a problem in northern latitudes, where very low temperatures can be reached in a few hours and extend over long periods (*Confalonieri et al., 2007l*). Reductions in cold-deaths due to climate change are projected to be greater than increases in heat-related deaths in the UK.

3.2.7 Water resources crisis

A number of climate-related trends have been observed that affect water resources. These include changes in precipitation, the crysosphere and surface waters (e.g., changes in river flows). Observed and projected impacts of climate change on freshwater systems and their management are mainly due to changes in temperature, sea level and precipitation variability. Sea level rise will extend areas of salinization of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. In an assessment of the scientific literature, *Kundzewicz et al. (2007)* concluded, with high confidence, that:

- The negative impacts of climate change on freshwater systems outweigh the benefits. All of the regions assessed in the IPCC Fourth Assessment Report (Africa, Asia, Australia and New Zealand, Europe, Latin America, North America, Polar regions (Arctic and Antarctic), and small islands) showed an overall net negative impact of climate change on water resources and freshwater ecosystems.
- Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater. It has been assessed that many of these areas, e.g., the Mediterranean basin, Western United States, Southern Africa, and north-eastern Brazil, would suffer a decrease in water resources due to climate change.

3.2.8 Environmental migration and conflict

General circulation models project that the future climate change will bring wetter coasts, drier mid-continent areas, and further sea level rise (*Scott, MJ, et.al., 1996*). Such changes could result in the gravest effects of climate change through sudden human migration. Millions might be displaced by shoreline erosions, river and coastal flooding, or severe drought.

Migration related to climate change is likely to be predominantly from rural areas in developing countries to towns and cities. In the short term climate stress is likely to add incrementally to existing migration patterns rather than generating entirely new flows of people. It is quite likely that environmental degradation, loss of access to resources (e.g., water resources) (*Desanker, P., et al., 2001*) and resulting human migration could become a source of political and even military conflict. Factors other than climate change may, however, be more important in affecting conflict. For example, Wilbanks *et al.* (2007) suggested that major environmentally influenced conflicts in Africa were more to do with the relative abundance of resources, e.g., oil and diamonds, than with resource scarcity. Scott *et al.* (2001) placed only low confidence in predictions of increased conflict due to climate change.

3.2.9 Aggregate economic impacts of climate change

Aggregating impacts adds up the total impact of climate change across sectors and/or regions. Examples of aggregate measures include economic cost (e.g., changes in gross domestic product (GDP) and the social cost of carbon), changes in ecosystems (e.g., changes over land area from one type of vegetation to another), human health impacts, and the number of people affected by climate change (*Smith, J.B., et al., 2001*).

Economic impacts are expected to vary regionally. For a medium increase in global mean temperature (2-3 °C of warming, relative to the average temperature between 1990-2000), market sectors in low-latitude and less-developed areas might experience net costs due to climate change. On the other hand, market sectors in high-latitude and developed regions might experience net benefits for this level of warming. A global mean temperature increase above about 2-3 °C (relative to 1990-2000) would very likely result in market sectors across all regions experiencing either declines in net benefits or rises in net costs.

Aggregate impacts have also been quantified in non-economic terms. For example, climate change over the 21st century is likely to adversely affect hundreds of millions of people through increased coastal flooding, reductions in water supplies, increased malnutrition and increased health impacts.

3.2.10 Climate change and ecosystems

Beyond the year 2050, climate change may be the major driver for biodiversity loss globally. It was projected by Fischlin *et al.* (2007a) that approximately 20 to 30% of plant and animal species assessed so far would likely be at increasingly high risk of extinction should global mean temperatures exceed a warming of 2 to 3 °C above pre-industrial temperature levels (Fischlin *et al.,* 2007b). The uncertainties in this estimate, however, are large: for a rise of about 2 °C the percentage may be as low as 10%, or for about 3 °C, as high as 40%, and depending on biota(Parry 2007a) (all living organisms of an area, the flora and fauna considered as a unit) the range is between 1% and 80%. As global average temperature exceeds 4 °C above pre-industrial levels, model projections suggested that there could be significant extinctions (40-70% of species that were assessed) around the globe.

3.2.11 Biogeochemical cycles

Climate change may have an effect on the carbon cycle in an interactive "feedback" process. Using the A2 SRES emissions scenario, Schneider *et al.* (2007:789) found that this effect led to additional warming by 2100, relative to the 1990–2000 period, of 0.1–1.5 °C. This estimate was made with high confidence. The climate projections made in the IPCC Fourth Assessment Report of 1.1–6.4 °C account for this feedback effect. On the other hand, with medium confidence, Schneider *et al.* (2007) commented that additional releases of GHGs were possible from permafrost, peat lands, wetlands, and large stores of marine hydrates at high latitudes.

3.2.12 Greenland and West Antarctic ice sheets

With medium confidence, the IPCC (2007b) concluded that with a global average temperature increase of 1–4 °C (relative to temperatures over the years 1990–2000), at least a partial deglaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheets would occur *(Parry 2007b).* The estimated timescale for partial deglaciation was centuries to millennia, and would contribute 4 to 6 metres (13 to 20 ft) or more to sea level rise over this period.

4. Conclusion

From the present study it is observed that substantial increase in energy demand in the developing countries, due to the strong economic growth is dominating energy markets today and subsequently increasing global population deplete fossil fuel reserves is making the sustainability vulnerable. Other major findings of the study are as under:

- The global population is expected to increase by 30% the next 25 years, where 80-90% of the increase is expected to be in developing countries.
- Limits to Growth – the 30 year update claims that the global system is currently in an un-sustainable situation, and that there are limits to growth on our planet – on resources, food, environment, and also in the population the earth can supply over time.
- Fossil fuel reserve depletion times for oil, coal and gas of approximately would be 35, 107 and 37 years, respectively. This means that coal reserves are available up to 2112, and will be the only fossil fuel remaining after 2042.
  - The oil price is currently very high at around $140 per barrel in nominal terms. This is much higher than after several other oil price crises, such as the Iran/Iraq war, Gulf war and 9/11 as per WTRG, 2008. According to OPEC (2007), OPEC benchmark crude price is assumed to remain in the $50 to $60 per barrel range in nominal terms for much of the projected period and rising further in the longer term with inflation.
  - Coal prices have had less fluctuation in comparison to oil in the last 50 years. The coal market depicts relatively constant coal prices in historical data. This trend will remain flat until the middle of the next decade, and then increase very slowly, reaching just over $60 per tonne by 2030.
  - Gas prices have generally followed the increase in oil prices since 2003, typically with a 1 year lag. The average transmission and distribution margin for delivered gas is projected to change from $2.38 per thousand cubic feet in 2006 to between $2.07 and $2.44 per thousand cubic feet in 2030.
- Due to fast energy requirement and subsequent high consumption of fossil fuel, greenhouse" gases such as Carbon Dioxide (CO_2) are tremendously increasing and causing Global warming is threat to the survival of mankind in today's scenario.
- The effects, or impacts, of climate change may be physical, ecological, social or economic and closely associated with Global warming. Climate change includes the instrumental temperature record, rising sea levels, and decreased snow cover in the Northern Hemisphere and sea ice, more frequent and intense heat waves, rising sea levels, and widespread ocean acidification, frequency of intense rainfall, and widespread ocean acidification.

- World Health Organization (WHO, 2009) estimated to have been responsible for 3% of diarrhea, 3% of malaria, and 3.8% of dengue fever deaths worldwide in 2004. Total attributable mortality was about 0.2% of deaths in 2004; of these, 85% were child deaths.
- Approximately 20 to 30% of plant and animal species would likely be at increasingly high risk of extinction when global mean temperatures exceed a warming of 2 to 3 °C above pre-industrial temperature levels. As global average temperature exceeds 4 °C above pre-industrial levels, there could be significant extinctions (40-70% of species that were assessed) around the globe.

Beyond the year 2050, climate change may be the major driver for biodiversity loss globally. The climate problem affects everyone, and everyone has a stake in deciding what should be done. It is for you to decide what actions you should take as an individual (in your home, your car, and so forth). Equally important, as a citizen you must decide which policies to support or oppose and make every one aware about disastrous consequences of the situation.

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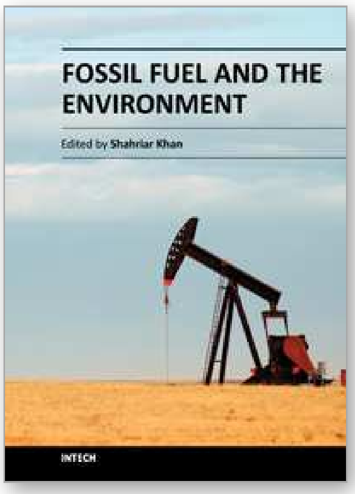

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The world today is at crossroads in terms of energy, as fossil fuel continues to shape global geopolitics. Alternative energy has become rapidly feasible, with thousands of wind-turbines emerging in the landscapes of the US and Europe. Solar energy and bio-fuels have found similarly wide applications. This book is a compilation of 13 chapters. The topics move mostly seamlessly from fuel combustion and coexistencewith renewable energy, to the environment, and finally to the economics of energy, and food security. The research and vision defines much of the range of our scientific knowledge on the subject and is a driving force for the future. Whether feasible or futuristic, this book is a great read for researchers, practitioners, or just about anyone with an enquiring mind on this subject.