Global Warming -2020 : Extended Abstract Title : Global Warming

Name : Hafiz Muhammad Anwar Saleem
Emai Id : hafizmuhammadajmalsaleem@gmail.com
Department Of Environmental Engineerng University Of Engineering And Technology, Taxila

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Abstract

Actuaries are becoming more aware of the combined impact of climate change and limitations of resources—two separate and very significant issues—putting at risk the sustainability of the current socio-economic systems that support our way of life. Although actuaries do not claim professional expertise in environmental issues, they can be guided by the growing body of knowledge publicly available from reliable scientific sources. Being particularly qualified to deal with modelling financial consequences of risks and uncertainties, the actuarial profession has a duty to provide training and education on climate change and sustainability so that its members are qualified to contribute to the

well-being of the society. In undertaking this exercise, the actuarial profession needs to be cognizant of the fact that even within the climate change science community there are differing views on the nature and amplitude of the risks and the profession should be aware of these differing views

Climate change is more than global warming. The rise in average temperature is only one indicator of broader changes also translating into extreme temperatures, drought, flooding, storms, rising sea levels, impacts on food production, and infectious diseases. Although the scientific community has been aware of the link between greenhouse gases (GHGs) and climate change for many years, world leaders have been slow to react and implement measures to mitigate the risks.

Key sources of information on climate change are synthesized by the successive reports of the Intergovernmental Panel on Climate Change (IPCC) created by the United Nations and the World Meteorological Organization in 1988. The prevalent view is that there is a significant anthropogenic contribution to the increase in atmospheric CO_2 and other GHGs resulting from fossil fuels emissions and deforestation. Unless new policies are implemented, global warming will exceed the threshold of

2°C agreed to by the parties to the UN Framework Convention on Climate Change for which Canada is a signatory.

In 1970, a paper by the Club of Rome pointed out that limited planet resources cannot support unlimited exponential growth. Even renewable resources will be depleted if they cannot be renewed fast enough. By some estimates, we are now using 50% more resources than the sustainable level. The 8 billion population projected by 2030 is twice

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the 4 billion the earth had to feed as recently as 1974. The pursuit of economic growth is compounding the growth in demand. Global warming is exacerbating the sustainability challenge as it may

reduce agricultural production and will result in physical damage resulting from extreme weather events, sea-level rise, etc.

Mitigating resource scarcity entails adopting new approaches such as a “circular economy”. This refers to an industrial economy that is restorative. It aims to rely on renewable energy; favors recycling; minimizes, tracks, and hopefully eliminates the use of toxic chemicals; and eradicates wastes through careful design. The mitigation strategy can be guided by a new paradigm defining a planetary boundary framework providing a science-based analysis of the risk that human overuse of resources will destabilize the earth system at the planetary scale.

The potential impact on actuarial methods and assumptions, especially future growth expectations, is pervasive in the work of actuaries and affects traditional life and non-life, health and pensions areas, investment practices, and newer areas like enterprise risk management. The actuarial profession has created interest groups at the national and international levels to help deepen the understanding of the quantitative aspects of sustainability. It can collect feedback and provide critical reviews of actuarial risk models, establish standards of practice, and promote the adoption of best practices. The North American actuarial associations are jointly creating actuarial climate and risk indexes that will monitor future changes and provide comparisons of benchmarks with the data published by climate scientists.

Actuaries can examine the different scenarios for climate change and use of resources to quantify the risks and provide guidance through cost/benefit analyses. Given the multidisciplinary nature of these issues, actuaries can benefit from inputs by non-actuarial entities and work in cooperation with other professionals to serve the public interest through optimizing policy options.

Note : This Work is presenting at 9 th international Summit on Global Warming and Environmental Science on Aug 10-11, 2020

INTRODUCTION

Every six to seven years, the Intergovernmental Panel on Climate Change (IPCC) issue a summary of the state of scientific research into climate change. Over the last few decades, their statements on the human contribution to recent global warming have grown increasingly definitive, from "a discernible human influence on the global climate" in the Second Assessment Report (Houghton et al. 1996) to "human influence has been the dominant cause of the observed warming since the mid-20th century" in the Fifth Assessment report (pp17, Qin et al 2014). Parallel to the strengthening scientific consensus in the IPCC reports, several other studies have sought to quantify the level of agreement on human-caused global warming among climate scientists. A synthesis of this research concluded that between 90 to 100% of scientists who publish climate research have concluded that humans are the predominant cause of global warming, with multiple studies converge on 97% consensus (Cook et al., 2016). Despite strong expert agreement, much of the public remain confused about the reality of human-induced global warming. Only 12% of the American public are aware that the scientific consensus is higher than 90% (Leiserowitz et al., 2017), a misconception referred to as the "consensus gap" to represent the chasm between public perception of consensus and the 97% consensus. The consensus gap is also found among science teachers (Plutzer et al., 2016) and journalists Wilson (2000). The U.S. public are also deeply polarized on the issue of climate change, with political liberals much more accepting of the reality of global warming relative to political conservatives (Cook and Lewandowsky, 2016; Leiserowitz et al. 2017). This polarization has been increasing over time (Dunlap, McCright, & Yarosh, 2016). Cook, J. (2019). Understanding and countering misinformation about climate change. In Chiluwa, I. & Samoilenko, S. (Eds.), Handbook of Research on Deception, Fake News, and Misinformation Online (pp. 281-306). Hershey, PA: IGI-Global. Addressing the issue of public polarization over climate change requires acknowledging and addressing the cause. In this case, a major contributor to polarization over climate change is decades of ideologicallydriven misinformation campaigns (McCright & Dunlap, 2010). Misinformation about climate change is found in a variety of outlets including mainstream media (Painter and Gavin, 2015) and social media (Harvey et al., 2017). In order to adequately respond to online misinformation about climate change, theoretical frameworks are required to better understand the impact of climate misinformation, the types of arguments employed, and effective interventions. This chapter will explore the research into the psychological impacts of climate misinformation, the techniques employed in denialist arguments, and the efficacy of various interventions in response. A growing body of research has explored the negative impacts of misinformation. A relatively small amount of climate misinformation, such as a few misleading statistics, is effective in lowering people's acceptance of climate change (Ranney & Clark, 2016). Misinformation targeting the scientific consensus significantly decreases perceived consensus, which subsequently lowers other climate attitudes including policy support (Cook, Lewandowsky, & Ecker, 2017; van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017). Misinformation about climate change also has a polarizing effect, disproportionately influencing political conservatives while having little to no effect on political liberals (Cook, Lewandowsky, & Ecker, 2017; van der Linden, Leiserowitz, Feinberg, & Maibach, 2015). This means that climate misinformation serves to exacerbate what is already a politically polarized public debate. An arguably more pernicious element of misinformation is its ability to cancel out the positive effects of accurate information. Denialist frames have been shown to reduce the positive effect of several different climate frames (McCright, Charters, Dentzman, & Dietz, 2016; van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017). This dynamic has significant consequences for mainstream media coverage of climate change. The journalistic norm of providing balanced coverage to both sides of a debate means that contrarian voices are often given equal weight with climate scientists (Painter and Gavin, 2015). However, false-balance media coverage has been shown to decrease public perception of scientific consensus (Cook, Lewandowsky, & Ecker, 2017). Finally, another overlooked negative impact of misinformation is its potential silencing effect. While most of the U.S. public are concerned or alarmed about climate change, less than half of segment of the population talk about the issue with friends or family (Leiserowitz et al., 2017). The main driver of this self-silencing is the misconception of pluralistic ignorance—most Americans who are concerned about climate change are ignorant of the fact that they're a plurality (Geiger and Swim, 2016). This misconception is self-reinforcing, resulting in a "spiral of silence" (Maibach et al., 2016). This chapter will explore two elements required in order to effectively counter misinformation. First, we require a stronger theoretical understanding of misinformation arguments and techniques. Second, experimental exploration of different refutation approaches is needed in order to develop evidence-based interventions. This chapter reviews research into both areas—understanding and responding to misinformation—and speculates on future lines of research.

What is Climate Change?

Climate change is the subject of how weather patterns change over decades or longer. Climate change takes place due to natural and human influences. Since the Industrial Revolution (i.e., 1750), humans have contributed to climate change through the emissions of GHGs and aerosols, and through changes in land use, resulting in a rise in global temperatures.[1] Increases in global temperatures may have different impacts, such as an increase in storms, floods, droughts, and sea levels, and the decline of ice sheets, sea ice, and glaciers.

1 http://www.wmo.int/pages/themes/climate/causes_of_climate_change.php

Process of Global Warming

The earth receives energy through radiation from the sun. GHGs play an important role of trapping heat, maintaining the earth's temperature at a level that can sustain life. This phenomenon is called the greenhouse effect and is natural and necessary to support life on earth. Without the greenhouse effect, the earth would be approximately 33°C cooler than it is today.[2] In recent centuries, humans have contributed to an increase in atmospheric GHGs as a result of increased fossil fuel burning and deforestation. The rise in GHGs is the primary cause of global warming over the last century.

There are three main datasets that are referenced to measure global surface temperatures since 1850.[3] These datasets show warming of between +0.8°C and +1.0°C since 1900.[4] Since 1950, land-only measurements indicate warming trends of between +1.1°C and +1.3°C,[7] as land temperatures tend to respond more quickly than oceans to the earth's changing climate. Figure 2.1 shows the global surface temperature trend (1880–2014).

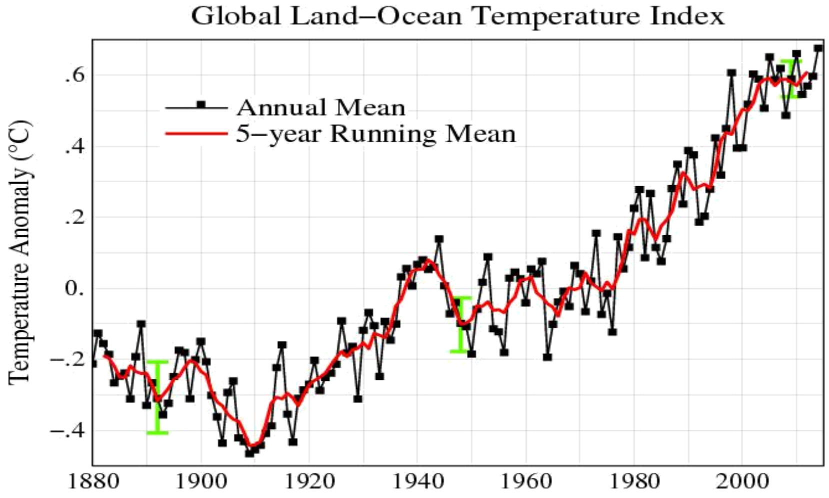


Figure 2.1: Instrumental temperature data 1880–2014.

Source: NASA Goddard Institute for Space Studies (GISS) [5]

While global warming is typically measured on multi-decadal time scales (30+ years), attributing trends over time periods of less than 30 years can be tricky, due to the influence of natural variability. Natural variability is defined as variations in climate that

are due to internal interactions between the atmosphere, ocean, land surface and sea ice. Those variations occur with or without climate change and are often described as "noise" or normal variations around a "normal" value. The El Niño Southern Oscillation (ENSO) cycle is the strongest source of internal natural variability due to the exchange of heat between the oceans and the surface along the equatorial Pacific. Because of this internal and natural variability, global warming does not necessarily occur linearly in response to the increase in GHG concentrations, and various periods of accelerated warming and warming slowdowns are a natural source of variability. Figure 2.2 shows two such periods in the context of longer-term global warming and illustrates natural variability occurring on a yearly basis.

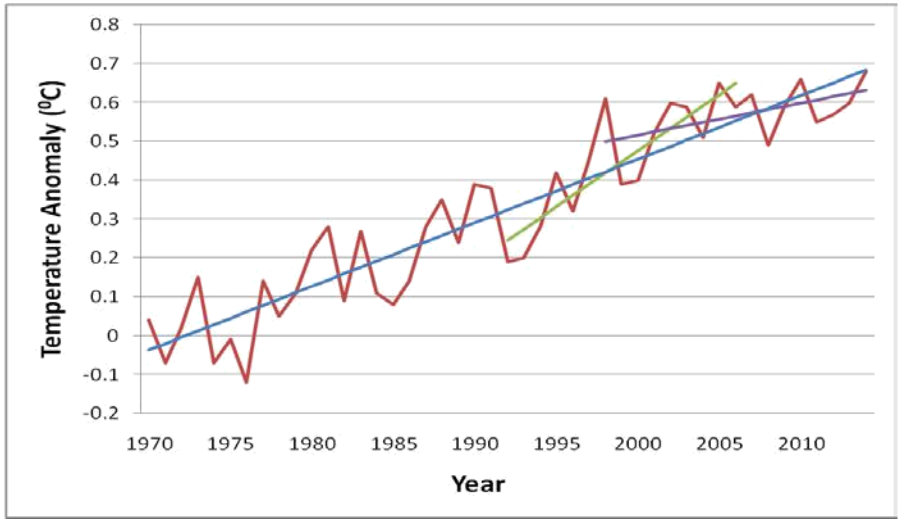


Figure 2.2: NASA GISS Global average temperatures. Forty-five-year trend is

shown in blue. The "warming slowdown" (purple trend line: 1998–2014) was

preceded by a period of accelerated warming (green trend line: 1992–2006). [6]

2 http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf

3 i) The Hadley Centre for Climate Prediction and Research, ii) Goddard Institute for Space Studies, and iii) National Climate Data Center.

4 Least-squares trend lines are calculated with the following tool: http://www.skepticalscience.com/trend.php

5 http://data.giss.nasa.gov/gistemp/graphs_v3/

What is Causing Global Warming?

The average temperature of the Earth is rising at nearly twice the rate it was 50 years ago. This rapid warming trend cannot be explained by natural cycles alone, scientists have concluded. The only way to explain the pattern is to include the effect of greenhouse gases (GHGs) emitted by humans.

Current levels of the greenhouse gases carbon dioxide, methane, and nitrous oxide in our atmosphere are higher than at any point over the past 800,000 years, and their ability to trap heat is changing our climate in multiple ways. One of the first things the IPCC concluded is that there are several greenhouse gases responsible for warming, and humans emit them in a variety of ways. Most come from the combustion of fossil fuels in cars, buildings, factories, and power plants. The gas responsible for the most warming is carbon dioxide, or CO2. Other contributors include methane released from landfills, natural gas and petroleum industries, and agriculture (especially from the digestive systems of grazing animals); nitrous oxide from fertilizers; gases used for refrigeration and industrial processes; and the loss of forests that would otherwise store CO2.

Gaseous abilities

Different greenhouse gases have very different heat-trapping abilities. Some of them can trap more heat than an equivalent amount of CO2. A molecule of methane doesn't hang around the atmosphere if a molecule of carbon dioxide will, but it is at least 84 times more potent over two decades. Nitrous oxide is 264 times more powerful than CO2.

Other gases, such as chlorofluorocarbons, or CFCs—which have been banned in much of the world because they also degrade the ozone layer—have heat-trapping potential thousands of times greater than CO2. But because their emissions are much lower than CO2, none of these gases trap as much heat in the atmosphere as CO2 does.

Climate change continues

Despite global efforts to address climate change, including the landmark 2015 Paris climate agreement, carbon dioxide emissions from fossil fuels continue to rise, hitting record levels in 2018.

Many people think of global warming and climate change as synonyms, but scientists prefer to use "climate change" when describing the complex shifts now affecting our planet's weather and climate systems. Climate change encompasses not only rising average temperatures but also extreme weather events, shifting wildlife populations and habitats, rising seas, and a range of other impacts.

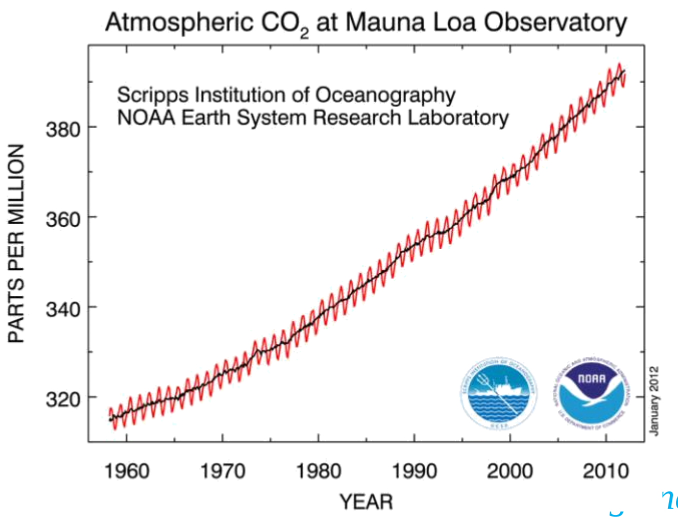


Figure 2.3: Growth of CO_2 concentrations at Mauna Loa Observatory since 1960[7]

Since 1951, approximately 100% of warming is attributed to anthropogenic forcing, while more than 100% is due to greenhouse gases due to offsets in anthropogenic aerosols (see Figure 2.4). Natural forcing and internal variability are considered to be negligible during this time period.

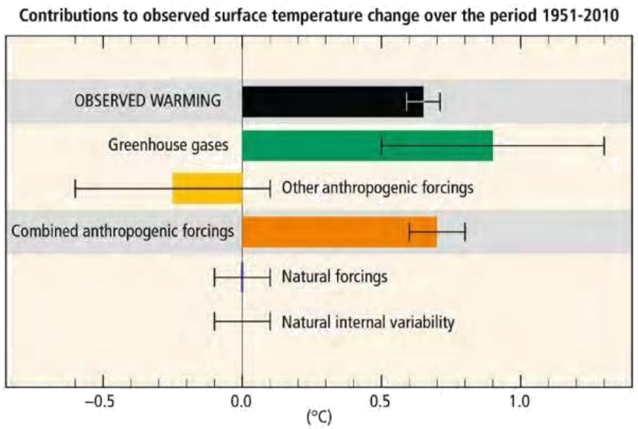


Figure 2.4: Growth$_2$ of CO concentrations at Mauna Loa Observatory since 1960.

[8]

Water vapor has an important indirect effect on temperature increases resulting from increasing GHG concentrations. Increased global temperature resulting from GHGs increases the capacity of the atmosphere to hold water vapor, thus acting as a positive feedback, as water vapor also produces a greenhouse effect. An increase in global temperature by 1°C results in approximately a 7% increase in atmospheric water vapor. “Therefore, although CO_2 is the main anthropogenic control knob on climate, water vapor is a strong and fast feedback that amplifies any initial forcing by a typical factor of between

7 http://www.esrl.noaa.gov/gmd/ccgg/trends/

8 http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf (p.6)

two and three. Water vapor is not a significant initial forcing but is nevertheless a fundamental agent of climate change”.[9]

Not all industrial emissions result in a warming bias. **Aerosols** resulting from industrial emissions have worked to offset about 26% of greenhouse warming due to blocking solar radiation from reaching the earth’s surface. There is, however, large uncertainty regarding the extent of influence that aerosols have on climate, mainly due to aerosol interactions with clouds.[10]

GHGs (particularly CO_2) have a longer **residence time** in the atmosphere (~100 years) compared to aerosols (only 10 days). As a result, the short-term effect of industrial pollution can be cooling followed by long-term warming. Aerosols are expected to offset a lower percentage of greenhouse warming in most future scenarios due to residence time, which allows for the possibility of an acceleration of future warming even without an acceleration of GHG concentrations.[11]

The **greenhouse effect** occurs when solar energy contacting the earth's surface is retransmitted to the atmosphere in the form of **infrared thermal radiation**. This radiation has a lower wave frequency than solar energy itself. GHG molecules absorb this thermal radiation at low frequencies, causing these molecules to vibrate. These greenhouse molecules then emit energy in the form of infrared photons, many of which return to the earth's surface. Non-GHGs such as oxygen and nitrogen do not absorb thermal radiation.[12]

The greenhouse effect is measured in terms of **Radiative Forcing** (RF) in units of watts per square meter (W/m^2). Since the Industrial Revolution, the total RF is estimated to have increased by approximately 2.3 W/m^2 (1.1 W/m^2 – 3.3 W/m^2; 90% confidence interval) mainly due to the net effect of increased GHG and aerosol concentrations in the atmosphere.[13]

The response of climate to the change in the earth's energy is referred to as **climate sensitivity**. **Equilibrium Climate Sensitivity** (ECS) is used to gauge the long-term response (i.e., 100+ years) to a doubling of CO_2 concentrations in the atmosphere, and estimates range from 1.5°C to 4.5°C according to the IPCC. This corresponds with an increase in RF of +3.7 W/m^2 (+3.0W/m^2 to +4.4 W/m^2). Alternatively, a **Transient Climate Response** (TCR) estimate is used to gauge shorter-term impacts (i.e., over 20 years) to a doubling of CO_2 concentrations in the atmosphere, and estimates range from 1.0°C to 2.5°C. The shorter- term estimates are lower due to the time it takes to heat up the oceans.[14]

9 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (pp. 666–667).

10 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf (pp. 13–14)

11 http://www.realclimate.org/index.php/archives/2007/02/aerosols-the-last-frontier/

12 http://scied.ucar.edu/carbon-dioxide-absorbs-and-re-emits-infrared-radiation

13 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf (p. 14; figure SPM-05)

14 http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_TS_FINAL.pdf (pp. 67–68; 82–85)

CAUSES AND EFFECTS OF CLIMATE CHANGE

The planet is warming, from North Pole to South Pole. Since 1906, the global average surface temperature has increased by more than 1.6 degrees Fahrenheit (0.9 degrees Celsius)—even more in sensitive polar regions. And the impacts of rising temperatures aren't waiting for some far-flung future–the effects of global warming are appearing right now. The heat is melting glaciers and sea ice, shifting precipitation patterns, and setting animals on the move.

Many people think of global warming and climate change as synonyms, but scientists prefer to use "climate change" when describing the complex shifts now affecting our planet's weather and climate systems. Climate change encompasses not only rising average temperatures but also extreme weather events, shifting wildlife populations and habitats, rising seas, and a range of other impacts. All of these changes are emerging as humans continue to add heat - trapping greenhouse gases to the atmosphere.

Scientists already have documented these impacts of climate change:

- Ice is melting worldwide, especially at the Earth's poles. This includes mountain glaciers, ice sheets covering West Antarctica and Greenland, and Arctic sea ice. In Montana's Glacier National Park the number of glaciers has declined to fewer than 30 from more than 150 in 1910.
- Much of this melting ice contributes to sea-level rise. Global sea levels are rising 0.13 inches (3.2 millimeters) a year, and the rise is occurring at a faster rate in recent years.
- Rising temperatures are affecting wildlife and their habitats. Vanishing ice has challenged species such as the Adélie penguin in Antarctica, where some populations on the western peninsula have collapsed by 90 percent or more.
- As temperatures change, many species are on the move. Some butterflies, foxes, and alpine plants have migrated farther north or to higher, cooler areas.
- Precipitation (rain and snowfall) has increased across the globe, on average. Yet some regions are experiencing more severe drought, increasing the risk of wildfires, lost crops, and drinking water shortages.
- Some species—including mosquitoes, ticks, jellyfish, and crop pests—are thriving. Booming populations of bark beetles that feed on spruce and pine trees, for example, have devastated millions of forested acres in the U.S.

Other effects could take place later this century, if warming continues. These include:

- Sea levels are expected to rise between 10 and 32 inches (26 and 82 centimeters) or higher by the end of the century.
- Hurricanes and other storms are likely to become stronger. Floods and droughts will become more common. Large parts of the U.S., for example, face a higher risk of decades-long "megadroughts" by 2100.
- Less freshwater will be available, since glaciers store about three-quarters of the world's freshwater.
- Some diseases will spread, such as mosquito-borne malaria (and the 2016 resurgence of the Zika virus).
- Ecosystems will continue to change: Some species will move farther north or become more successful; others, such as polar bears, won't be able to adapt and could become extinct.

Future Emissions Pathways

There are many factors that can influence future GHG emissions. The 2013 IPCC report uses Representative Concentration Pathways (RCPs) to

RCP scenarios. Keeping warming to under 2°C worldwide (relative to 1750) is widely considered to be an important target in reducing the risk of dangerous warming, but is unlikely to be achieved without substantial reductions in GHG emissions.[17]

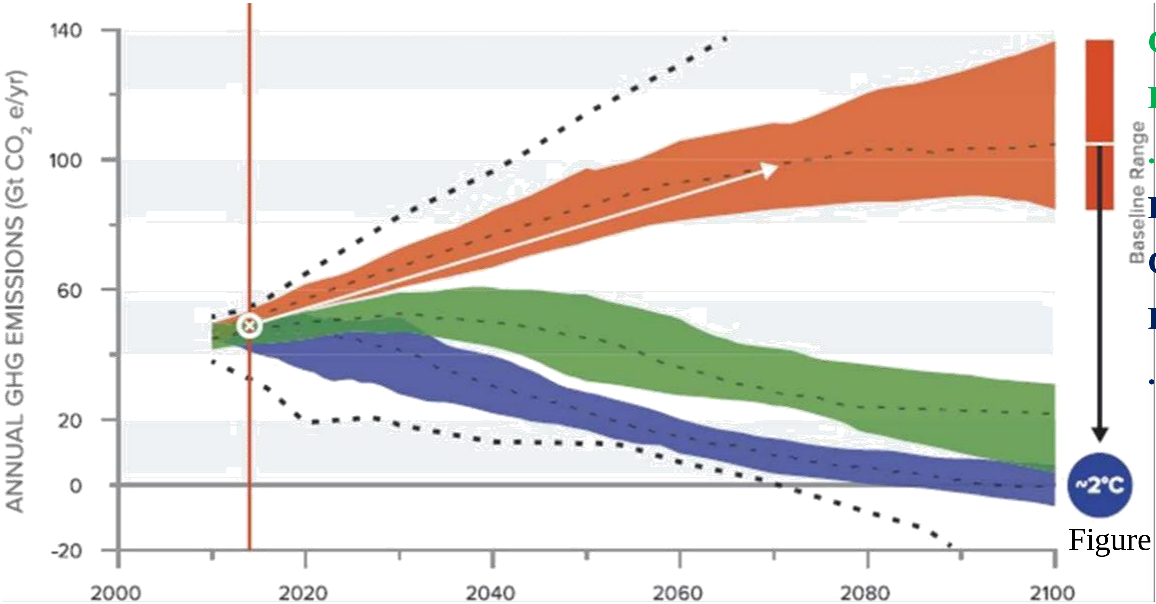
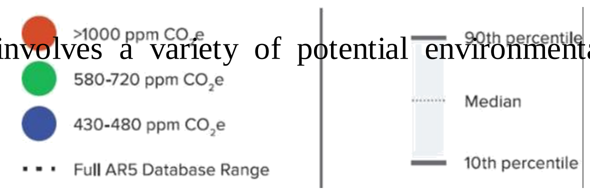


Figure 2.6 Future GHG Emissions Pathways, 2010–2100 (Gt CO_2e/year)

Environmental and Social Impacts of Climate Change

Climate change involves a variety of potential environmental, social, and economic



impacts. In most situations, these impacts will be adverse; in a few isolated situations, these could be more favorable (such as increased crop yield). The severity of the adverse impacts will increase with the rise in the average global temperature. Even if global warming is kept within 2°C relative to pre-industrial levels, adverse impacts will be experienced, and the world will need to take appropriate measures to adapt to new climate conditions. If, despite the world efforts, the temperature increase goes beyond the 2°C threshold, it has been assessed that the consequences would become increasingly severe, widespread and irreversible.

17 http://newclimateeconomy.report/wp-content/uploads/2014/08/NCE_GlobalReport.pdf

Canada has already become warmer by 1.5°C on average from 1950 to 2010.[18] Climate change is expected to make extreme weather events, such as heat waves, acute rainfall, floods, storms, droughts, and forest fires, more frequent and/or more severe in Canada. Worldwide, the areas in which adverse impacts will be experienced are described below.

Floods and Droughts

Floods are expected to occur more frequently on more than half of the earth's surface. In some regions, they could decrease. During winter, snowfalls are expected to decrease in mid-latitudes, resulting in less significant snowmelt floods during the spring season. In Canada, increased rainfall is forecasted for the entire country.

On the other hand, meteorological droughts (less rainfall) and agricultural droughts (drier soil) are projected to become longer or more frequent in some regions and some seasons, especially under the RCP 8.5, because of reduced rainfall and increased evaporation, like in British Columbia and the Prairies. More severe droughts will put additional pressure on water supply systems of dry areas, but could be manageable in wetter areas, assuming adaption measures are implemented.

Reduction in Water Resources

Renewable water supply is expected to decline in certain areas and expand in others. In regions where gains are expected, temporary deficits of water resources are still possible because of increased fluctuations of stream flow (caused by higher volatility of precipitation and increased evaporation during all seasons) and of seasonal cutbacks (because of lower accumulation of snow and ice). Clean water supply may also decrease due to a warmer environment inducing lower water quality. For example, algaeproducing toxins could damage the quality of sources such as lakes. Such overall decline in renewable water supply will intensify competition for water among agriculture, ecosystems, settlements, industry, and energy production, affecting regional water, energy, and food security.

Rising Sea Levels

In some regions such as the U.S. Eastern Coast, tides are reaching up to three feet higher than they used to 50 years ago.[20] Rising sea levels will have more and more negative consequences near the coasts—such as flooding, erosion of the coasts, and submergence of low-lying regions—putting at risk populations, infrastructure, animals, and vegetation near the coasts. Low-lying regions (like Bangladesh) and whole islands (like the Maldives and Kiribati) are at risk of destruction in the short term from rising ocean levels, floods, and more intense storm urges.

Around the world, 15 of the 20 biggest urban regions are located near the coast (14 in Asia) and around 200 million people reside fewer than 30 miles from the ocean. Based on a Reuter's analysis, more than $1.4 trillion worth of real estate would be at risk on the coast

18 http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf

19 http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap3_FINAL.pdf

20 http://reut.rs/1MbnkBi

of the U.S. alone. "An increasing percentage of the U.S. population and economic assets— including major U.S. cities and financial hubs such as Miami, Lower Manhattan, New Orleans, and Washington DC—are located on or near coasts, and they are threatened by sea-level rise."

Changes in Ecosystems

In the past millions of years, climate changes have naturally occurred at slower paces, permitting the ecosystems to adapt. However, in the 20th century many argue that we have entered the Anthropocene.[23] Species extinction rate has exceeded by up to 100 times the "normal" pace (i.e., without anthropogenic impact). We are facing a major biodiversity crisis and we might even be entering a sixth "mass extinction".[24] In the 21st century and beyond, the risk of extinction that land and aquatic species are exposed to is higher under all RCP scenarios. As early as 2050, the rapid changes that are currently taking place are expected to jeopardize both land and ocean ecosystems, particularly under RCP 6.0 and RCP 8.5. It may be noted that the changes in ecosystems involve much more than climate change. Massive extinctions are caused by many factors including urbanization, increased world population, etc. Of course, climate change has made its contribution which will amplify with time.

Even under RCPs projecting modest global warming levels (RCP 2.6 to RCP 6.0), most ecosystems will remain vulnerable to climate change. The increase in average temperatures will cause a lot of terrestrial and aquatic species to migrate towards more adequate climates, but many of them will not be able to do so quickly enough during the 21st century under RCP 4.5 to RCP 8.5, thus jeopardizing biodiversity. This migration trend is already being observed for vegetal and animal species in Canada.

Food Production and Security

Obvious climate change impacts on terrestrial food production can already be observed in some sectors around the globe. In the past few years, climate extremes such as droughts have occurred in major producing areas, resulting in many episodes of price hikes for food and cereals. Although these effects are beneficial in certain areas, adverse consequences are more frequent than favorable ones, especially, because key production areas (e.g.

California) are in historically favorable areas which will become unfavorable. Many climate change impacts will increasingly affect food security—particularly in low-latitude regions—and will be exacerbated by escalating food demand. Forecasted ocean-level rise will threaten crucial food-producing areas along the coasts, such as India and Bangladesh, which are major rice producers.

21 http://biospherology.com/PDF/MAB_2014.pdf (p. 27)

22 http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-FrontMatterA_FINAL.pdf (chapters 4–6)

23 Crutzen, P. J., and E. F. Stoermer (2000). "The 'Anthropocene'". *Global Change Newsletter*

41: 17–18.

24 http://advances.sciencemag.org/content/1/5/e1400253

25 http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf

26 http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap7_FINAL.pdf

Climate change is also a key political issue, and its consequences, such as food insecurity, are already generating conflict in vulnerable regions around the globe. For example, in northern Africa, there is increasing evidence that even though climate change impacts such as food insecurity are not the "cause" of the 2011 Arab spring, they may have precipitated the uprisings. The expected impacts of climate change—such as extreme temperatures, flooding, droughts, rising ocean levels, and ocean acidification— will not only exacerbate existing tensions but will also be a major challenge for homeland security.

Human Health

If climate change keeps occurring as forecasted under RCP scenarios, it will influence human health in three different ways:

- Extreme weather events have direct impacts such as increase
- d risks of death and disability.
- Alterations of the environment and ecosystems indirectly affect human health, such as a higher prevalence of waterborne illnesses caused by higher temperatures or increased death and disability rates during extreme heat episodes. Climate change will exacerbate current illness loads, especially in regions with fragile healthcare systems and lesser ability to adapt. Poor regions—especially poor children—are expected to be the most vulnerable to climate-related health risks.
- Other indirect consequences pertaining to societal systems will arise, such as under- nutrition and mental disorders caused by stressed food production systems, increased food insecurity and relocation resulting from climate extremes.

Economic Impacts of Climate Change

Likely, environmental and social impacts of climate change discussed above will have financial consequences on many sectors across the economy. Based on the Stern Review on the Economics of Climate Change, the price of doing nothing about climate change will be equivalent to an annual loss of 5% or more in global GDP, *ad infinitum*. If a broader spectrum of effects and contingencies is included in the analysis, the estimated costs could reach 20% of GDP or more. In comparison, the price of managing to stabilize atmospheric GHG levels within a range of 500–550 ppm of CO_2 equivalent is estimated to be 1% of global GDP annually, if we begin implementing sharp mitigation measures now. Therefore, this cost/benefit analysis is a clear economic incentive to take significant actions sooner than later.

A fundamental transformation away from fossil fuels and towards renewable energy at a global level such as envisaged under RCP 2.6 will have very large local and global consequences for all economic sectors and presents both opportunities and downside risks. For example, the growth in energy demand has historically been highly correlated to gross domestic product (GDP) growth per capita, especially in low- and middle-income economies.[31] Moving away from fossil fuels involves a risk of "stranded assets", but taking action to mitigate climate change will generate substantial commercial opportunities, with the development of new markets such as energy technologies and other goods and services that are low-carbon. "These markets could grow to be worth hundreds of billions of dollars each year, and employment in these sectors will expand accordingly. The world does not need to choose between averting climate change and promoting growth and development.[32]

Thus, both physical impacts of climate change and adaptation measures will have consequences on basically all sectors across the economy. Here are some of them.

- The increased frequency and magnitude of extreme weather events will affect the insurance industry, causing greater damage and higher loss volatility to property/casualty, life, and health insurance. It may make it more difficult for insurance systems to provide coverage at a reasonable cost and to increase the risk- based capital.

27 http://biospherology.com/PDF/MAB_2014.pdf
28 http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap11_FINAL.pdf
29 http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap10_FINAL.pdf
30 http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete. pdf

- Impacts on human health will expand the need for healthcare and add stress to existing healthcare systems.
- The financial services industry may also be impacted at different levels, based on their asset/loan portfolios' vulnerability to climate change.
- Weather-sensitive sectors such as agriculture, forestry, fisheries, tourism, hydroelectricity, transportation, and mining will inevitably be impacted.
- Economic development and productivity may decline.
- Extreme climate and weather events may threaten the proper functioning of pipelines, electricity grids, and transport infrastructure.
- The need for heating may lessen, and the need for cooling intensify, in properties of both individuals and businesses.

Estimations and projections of economic costs are complex and rely upon a multitude of assumptions that are difficult to determine. They vary widely among different countries. "Further research, collection, and access to more detailed economic data and the advancement of analytic methods and tools will be required to assess further the potential impacts of climate on key economic systems and sectors."

Concluding Observations

The objective of the paper was to present the views on climate change and resource sustainability that have been widely accepted in the world. On any contentious issue, it is impossible to have 100% acceptance. No doubt, there are differing views on these dual issues. Each differing view must be evaluated on its own merits. On the other hand, many actuaries must translate this information to assess past, current and future risks.

The earth has been showing a rapidly warming trend. This has been primarily caused by the increasing concentration of the GHGs—particularly carbon dioxide. There is worldwide acceptance for the fact that the largest contributor to the increase in CO_2 concentration is the burning of fossil fuels and deforestation. This is causing climate change that will have a very wide-ranging impact on life on earth. This will include increased frequency of extreme temperatures, floods, hurricanes, storms, droughts, and sea levels, to name a few. If no immediate action is taken and the concentration of GHGs can increase unchecked, the resulting consequences could be disastrous, and humanity could reach a point of no return.

The world community has accepted the need to limit the increase in the earth's temperature to 2°C and initiate changes to achieve this objective. This will require the world to move away from burning fossil fuels and effectively reach a stage of zero carbon emissions.