# Technical Research Studies on

## "Preparation of Technical Manual on Climate Change Education and Awareness"

# In Collaboration with

## Sustainable Development Policy Institute (SDPI)

SDPI
Sustainable Development Policy Institute

## Global Change Impact Studies Centre (GCISC)

Ministry of Climate Change

Government of Pakistan

# Technical manual on climate change education and awareness

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## Module: Climate Change Education and Awareness

The modern industrial age enhanced the economies of the present-day developed countries and gave rise to unique improvements in the standard of living for much of mankind. It also gave birth to environmental pollution as we know it today. This environmental pollution played a part in the degradation of this planet and began a slow process which has accelerated over time the transformation of the Earth's surface and atmosphere. An increasing population has meant that meeting the ever-increasing demand for goods and services of the modern age continues to require extensive use of a seemingly infinite natural resource base. The challenge imposed on the Earth to provide the necessary raw materials, energy, and waste disposal processes for mankind's production and consumption has had many consequences for the health of ecosystems around the globe. Of the many problems generated by our economic and industrial progress, climate change is one that dominates media headlines. The current warming trend of the Earth's atmosphere that started with the industrial revolution has given scientists, politicians, and concerned individuals around the world cause for great apprehension.

Climate change is a complex global problem because it is intertwined with many other issues, such as economic development and poverty reduction. Developing countries are the least responsible for climate change, yet the most at risk from its effects. Eradicating poverty and improving living conditions via the attainment of the Sustainable Development Goals (SDGs) must remain a priority. The challenge is to accomplish the SDGs while reducing dependence on carbon, promoting climate resilience and ensuring balanced economic development.

Climate change resulting from human-induced greenhouse gas emissions is affecting the Earth in ways that are and will continue to significantly impact the people and our environment for generations to come. One aspect of climate change refers to the increase in average global temperatures resulting from more greenhouse gases in the atmosphere. The impacts of global temperature increase on the Earth are pervasive and significant, including sea level rise, changes in precipitation and humidity patterns, increased extreme weather events, and more climate variability. We refer to all of these changes as 'climate change'.

Given the enormous significance of climate change for the people and our environment, it is imperative that university students gain broad knowledge on climate change topics, including causes and effects, mitigation and adaptation, application of tools and technologies and effective communications. Understanding climate change has relevance for students across many disciplines because it includes learning topics related to the physical sciences, biological sciences, environmental science, social science, agriculture, forestry, health and medicine, communications, and public services.

This module consists of a conceptual framework, a glossary of subject related terminologies. This module has been developed to be flexible and adaptable to a wide range of educational contexts.

## Module Aim

This module aims to provide students of higher education institutes with necessary knowledge, skills and attitudes on a broad range of climate change topics, including causes and impacts of climate change, mitigation and adaptation, application of tools and technologies and effective communications. Its purpose is to raise awareness about climate change and enhance the rudimentary understanding of a highly important subject. Strengthen the capacity of the State to provide quality climate change education for sustainable development at primary and secondary school level through: improved education policy, analysis, research and planning; teacher education and training of education planners; training on curriculum review/reform. (Add from https://www.campuscruzroja.org/mod/scorm/player.php?a=97&currentorg=&scoid=557&sesskey=FarrXBHWGa&display=popup&mode=normal)

## Module Format

This module is divided into three main sections. Each section covers the most critical topics and offers an elementary explanation of the terminology of climate change related aspects.

**Section I: How and Why the Climate is changing?**

**Section II: Impacts of Climate Change on People and Environment (social economic and environment)**

**Section III: Responses to Climate Change - Mitigation and Adaptation**

## Target groups

- **Main target groups**: students (undergraduates and graduates)
- **Other audience:** general public

## Learning Outcome

On completion of this module, readers will be able to:

- Describe the components, drivers, and interactions of climate.

- Analyze causes and effects of climate change (by using gender sensitive method, tools and techniques).
- Explain the relationship between human activities and climate change, with emphasis on ecosystems and conservation.
- Assess (by using gender sensitive method, tools and techniques) the impacts of human activities on climate and the impacts of climate change on ecosystem services and socio-economic systems.
- Identify potential responses and solutions to climate change challenges, and assess (considering gender needs and priorities) their feasibility and potential effectiveness.
- Apply appropriate communication strategies on climate change mitigation and adaptation to different types of audience.

## Section 1 - How and Why the Climate is changing?

This section gives a comprehension of the physical science premise of environmental change, including what we think about the atmosphere and environmental change, what causes environmental change, how environmental change is bringing about greater instability and more significant extremes in atmosphere, and how we utilize atmosphere models to comprehend atmosphere frameworks and roll out projections about future improvements. The three topics covered in this section are:

- Introduction to climate change
- Causes of climate change
- Climate intensification: floods, droughts and cyclones

## Introduction to Climate Change

### 1.1.1 What is Climate Change?

Climate change is a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). (IPCC, 3rd Assessment Report: Climate Change 2001)

Climate change is also referred to as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (The UNFCCC, Article 1)

Climate change might be because of characteristic interior procedures or outside powers, or due to the anthropogenic changes in the composition of the atmosphere or on land.

Another simple definition of climate change could be the impacts manifested in the form of irregular changes and more severe weather patterns, leading to floods and other natural calamities.

### 1.1.2 What is Climate Variability?

Climate variability refers to variations in the mean state and other statistics (such as the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). (IPCC, 3rd Article)

### 1.1.3 How do Climate and Weather differ?

**Weather**

The actual state of the atmosphere in a period of several hours up to a few days (in a given place). The study of weather is known as Meteorology. Meteorology is usually concerned only with the lowest region of the atmosphere, the troposphere.

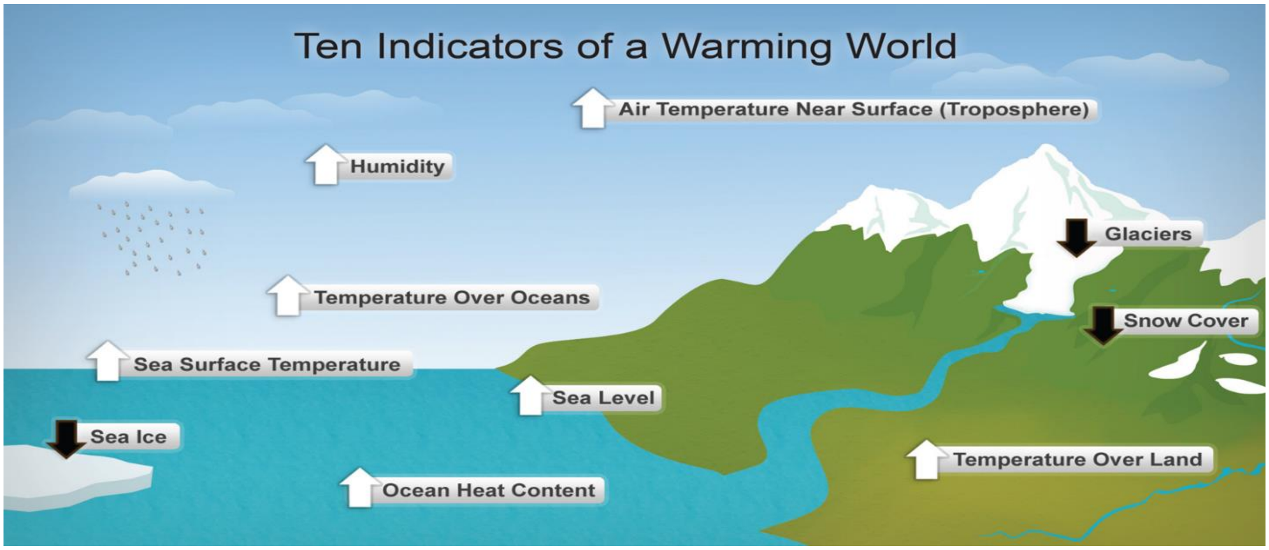
**Climate**

A statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years.

The classical period is three decades or 30 years, which are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. Climate can, however, change over long periods of time, and the topic of climate change is currently of practical importance, because of the known or potential effects of human activity on local, regional, or even world-wide climates.

*Climatology*, the study of climate, differs from meteorology in that climate is the long-term pattern of temperature, precipitation, wind patterns, etc. at a particular location, over periods of a year or more, whereas weather is the current (or very near-term) state of affairs at the location or region of interest.

### 1.1.4 What are the Primary Indicators of Climate Change?




Source: NOAA NCDC based on data updated from Kennedy et al. 2010

The figure above shows some of the indicators measured globally over many decades that show that the Earth's climate is warming. White arrows in the figure indicate increasing trends, and black arrows indicate decreasing trends. All the indicators expected to increase in a warming world are, in fact, increasing, and all those expected to decrease in a warming world are decreasing. (Figure source: NOAA NCDC based on data updated from Kennedy et al. 2010). For better understanding each indicator is briefly discussed below.

1. **Increasing air temperature**

The average air temperatures are rising, and as a result, the frequency and severity of droughts and heat waves are increasing. Intense droughts can lead to failed crops and low water supplies, many of which are deeply affecting several parts of the world.

2. **Glacier Melting**

The disappearance of glaciers is one of the clearest signs of climate change. People who rely on melting glacier water are facing shortages, and in many regions, the situation is only getting worse. In a world unaffected by climate change, glacier mass stays balanced, meaning the ice that evaporates in the summer is fully replaced by snowfall in the winter. However, when more ice melts than is replaced, the glacier loses mass. And the people who depend on melting ice for water to support their farming and living needs are deeply affected.

3. **Rising sea levels**

Sea levels have been rising for the past century. And the pace is only increasing in recent years as glaciers melt faster and water temperatures increase, causing oceans to expand. Eight of the ten largest cities in the world are near a coast. This means millions of people are at risk as sea levels rise, storms intensify, and more extreme flooding occurs. Additionally, marine life is threatened as salt water intrudes into fresh water aquifers, many of which support human communities and natural ecosystems.

4. **Humidity**

More humidity means more water vapor is in the air, making it feel stickier in hot weather. Water vapor itself is an important part of the water cycle, and it contributes to the earth's natural greenhouse effect. Air conditioners have to work much harder to make us feel cool as the amount of water vapor in the air increases. This means more energy use, which can in turn contribute to more climate change.

5. **Increasing ocean heat content**

The ocean stores and releases heat over long periods of time. This is a natural and important part of stabilizing the climate system. Natural climate patterns occur regularly because of warmer ocean waters and influence areas like regional climates and marine life. The increased heat content leads to higher sea levels, melting glaciers, and stress to marine ecosystems.

6. **Sea surface temperature**

Water temperatures at the ocean's surface are going up. The normal pattern is that the ocean surface warms as it absorbs sunlight. The ocean then releases some of its heat into the atmosphere, creating wind and rain clouds.

Conversely, as the ocean's surface temperature continues to increase over time, more and more heat is released into the atmosphere. This additional heat can lead to stronger and more frequent storms like tropical cyclones and hurricanes.

7. **Decreasing snow cover**

Snow is important as it helps control how much of the sun's energy Earth absorbs. Light-colored snow and ice reflect this energy back into space, helping keep the planet cool.

However, as the snow and ice melts, it's replaced by dark land and ocean, both of which absorb energy. The amount of snow and ice loss in the last 30 years is higher than many scientists predicted, which means the Earth is absorbing more solar energy than had been projected.

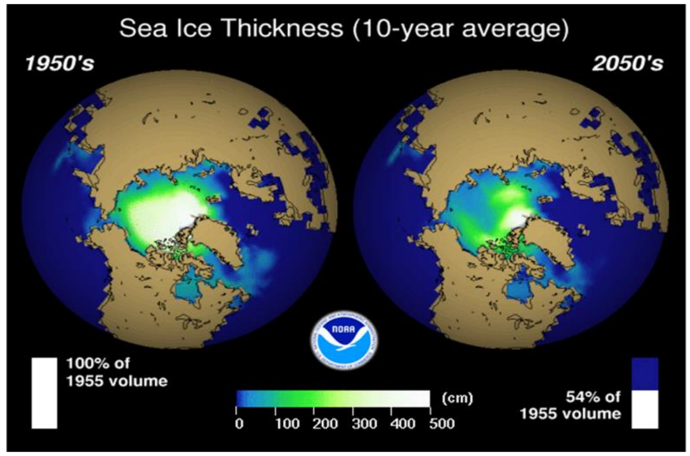
8. **Increasing temperature over the land**

The lowest layer of the atmosphere, called the troposphere, is the layer we are most familiar with, it is where we live. This lowest layer of the atmosphere is warming as greenhouse gases build up and trap heat that radiates from the Earth's surface.

The human activity, particularly the burning of fossil fuels, caused this increase in atmospheric temperatures. In fact, carbon dioxide levels have increased about 40 percent since the Industrial Revolution began in 1750 and are likely to increase even more.

9. **Decreasing sea ice**

It has been revealed that the area covered by sea ice in the Arctic is shrinking, and it's continued a downward trend for the past 30 years. The Arctic ice cap grows each winter when there's less sunlight, and shrinks each summer when days are longer, reaching its lowest point of the year in September. According to the normal pattern, the sea ice reaches its lowest cover in September, and then grows again during the winter. However, exceptionally warm winter temperatures can affect the re-growth, and during October 2016 – January 2017 the lowest daily extent of sea ice in record was witnessed, likely due to record warm temperatures in the Arctic. The volume of sea ice is however decreasing and the trend continues in 2017.




The figure on the right shows the prediction of sea ice thickness from 1950s to 2050s. The reduction over time is clearly visible in the picture.

10. **Increasing temperature over the ocean**

Just as temperatures over land are getting warmer, so are temperatures over oceans. Warmer air near the ocean surface leads to increased evaporation, and more evaporation means more water vapor in the air. The increased amount of water vapor not only contributes to extra warming, but may feed heavy precipitation events and act as fuel for potential hurricanes, if other conditions are right.

## 1.2 Causes of climate change

The earth's climate is naturally variable on all time scales. However, its long-term state and average temperature are regulated by the balance between incoming and outgoing energy, which determines the Earth's energy balance. Any factor that causes a sustained change to the amount of incoming energy or the amount of outgoing energy can lead to climate change.

Different factors operate on different time scales, and not all of those factors that have been responsible for changes in earth's climate in the distant past are relevant to contemporary climate change. Factors that cause climate change can be divided into two categories – first category are those which are related to natural processes and the second are those which are related to human activity.

In addition to natural causes of climate change, changes internal to the climate system, such as variations in ocean currents or atmospheric circulation, can also influence the climate for short periods of time. This natural internal climate variability is superimposed on the long-term forced climate change.

### 1.2.1 Natural Causes

The Earth's climate can be affected by natural factors that are external to the climate system, such as changes in volcanic activity, solar output, and the Earth's orbit around the Sun. Some major natural causes are briefly discussed below.

1. **Volcanic Activity**

Of these, the two factors relevant on timescales of contemporary climate change are changes in volcanic activity. Volcanic eruptions are episodic and have relatively short-term effects on climate.

Volcanic eruptions discharge carbon dioxide, but they may also emit aerosols, such as volcanic ash or dust, and sulfur dioxide. Aerosols are liquids and solids that float around in the air. They may also include soot, dust, salt crystals, bacteria, and viruses. Aerosols scatter incoming solar radiation, causing a slight cooling effect. Volcanic aerosols can block a percentage of sunlight and cause a cooling that may last for 1-2 years.

In violent eruptions, volcanoes release ash particles and sulfur dioxide (SO2) into the stratosphere. The larger particles settle after a few days while the sulfur dioxide combines with water vapor to from sulfuric acid (H2SO4) and sulfate particles, known together as sulfurous aerosols. Winds transport these sulfurous aerosols around the planet in easterly or westerly directions.

2. **Movement of Tectonic Plates**

As tectonic plates move over geological timescales, landmasses are carried along to different positions and latitudes. These changes affect global circulation patterns of air and ocean water and the climate of the continents.

3. **Changes in Solar Radiation**

Changes in solar irradiance have contributed to climate trends over the past century but since the Industrial Revolution, the effect of additions of greenhouse gases to the atmosphere has been over 50 times that of changes in the Sun's output; Earth's temperature depends on the balance between energy entering and leaving the planet’s system. When incoming energy from the sun is absorbed by the Earth system, the planet warms. When the sun's energy is reflected back into space, Earth avoids warming. When absorbed energy is released back into space, Earth cools.

Scientists have pieced together a record of Earth's climate by analyzing a number of indirect measures of climate such as ice cores, tree rings, glacier lengths, pollen remains, and ocean sediments, taken on a scale of the entire history of Earth.

| Indicator | Property measured | Time resolution | Time span | Climate-related information obtained |
|---|---|---|---|---|
| Tree rings | Width, density, isotopic ratios, trace elements | Annual | Centuries to millennia | Temperature, rainfall, fire |
| Lake and bog sediments | Deposition rates, species assemblages from shells and pollen, macrofossils, charcoal | Annual | Millennia | Rainfall, atmospheric water balance, vegetation type, fire |
| Coral growth rings | Density, isotope ratios, fluorescence | Annual | Centuries | Temperature, salinity, river outflows |
| Ice cores | Isotopes, fractional melting, annual layer thickness, dust grain size, gas bubbles | Annual | Millennia | Temperature, snow accumulation rate, windiness, gas concentrations |
| Ocean sediment cores | Species assemblages from shells and pollens, deposition rates, isotopic ratios, air-borne dust, pollen | Usually multi-decadal or centuries | Millennia | Sea temperatures, salinity, acidity, ice volumes and sea level, river outflows, aridity, land vegetation |
| Boreholes | Temperature profile | Decades | Centuries | Surface air temperature |
| Old groundwater | Isotopes, noble gases | Centuries | Millennia | Temperature |
| Glacial moraines | Maximum glacier length | Decades | Centuries to millennia | Temperature and precipitation |
| Sand dunes | Orientation, grain size | Centuries | Millennia | Wind direction and speed, aridity |
| Coastal landforms | Ledges, former beach lines, debris lines | Decades to centuries | Decades to millennia | Former sea-level, tropical cyclones |
| Documentary evidence | Reports of extremes, harvests, dates of break-up of river or lake ice | Annual | Centuries to millennia | Temperature, precipitation |

Sources of paleoclimate information

This record shows that the climate system varies naturally over a wide range of time scales. In general, climate changes prior to the Industrial Revolution in the 1700s can be explained by natural causes, such as changes in solar energy, volcanic eruptions, and natural changes in greenhouse gas (GHG) concentrations.

### 1.2.2 Human Causes

Recent climate changes, however, cannot be explained by natural causes alone. Research indicates that natural causes do not explain most observed warming, especially warming since the mid-20$^{th}$ century. Rather, it is extremely likely that human activities have been the dominant cause of that warming.

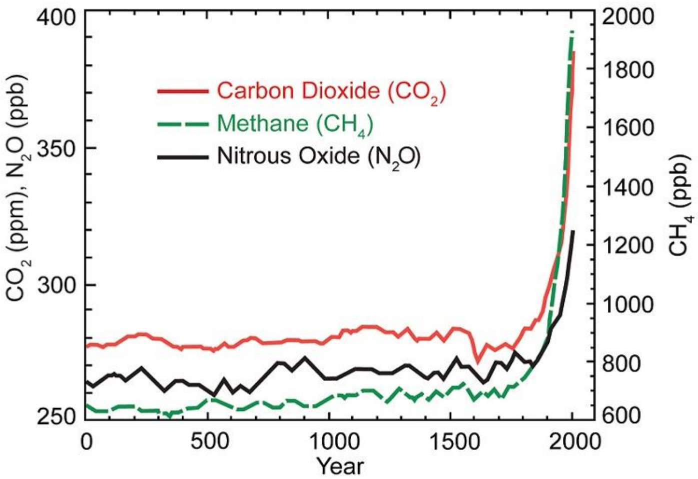
Climate change is also caused by human activities, such as the burning of fossil fuels and the conversion of land for forestry and agriculture. Since the beginning of the Industrial Revolution, these human influences on the climate system have increased substantially. In addition to other environmental impacts, these activities change the land surface and emit various substances to the atmosphere. These in turn can influence both the amount of incoming energy and the amount of outgoing energy and can have both warming and cooling effects on the climate. The dominant product of fossil fuel combustion is carbon dioxide, a greenhouse gas. The overall effect of human activities since the Industrial Revolution has been a warming effect, driven primarily by emissions of carbon dioxide and enhanced by emissions of other greenhouse gases.

Humans are increasingly influencing the climate and the earth's temperature by burning fossil fuels, cutting down rainforests and farming livestock. A few of the major human induced causes are discussed below.

1. **Greenhouse gas effect**

Since the Industrial Revolution began around the year 1750, human activities have contributed substantially to climate change by adding $CO_2$ and other heat-trapping gases to the atmosphere. These greenhouse gas emissions have increased the greenhouse effect and caused Earth's surface temperature to rise. The primary human activity affecting the amount and rate of climate change is greenhouse gas emissions from the burning of fossil fuels.

The build-up of greenhouse gases in the atmosphere has led to an enhancement of the natural greenhouse effect. It is this human-induced enhancement of the greenhouse effect that is of concern because ongoing emissions of greenhouse gases have the potential to warm the planet to levels that have never been experienced in the history of human civilization. Such climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences.




This graph shows the increase in greenhouse gas (GHG) concentrations in the atmosphere over the last 2,000 years. Increases in concentrations of these gases since 1750 are due to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion molecules of air.

Source: U.S. National Climate Assessment (2014)

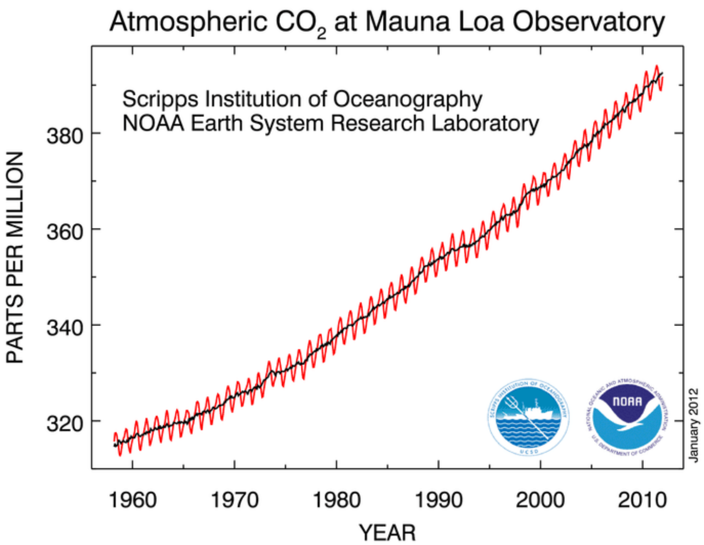
**Greenhouse gases**

Some gases in the Earth's atmosphere act a bit like the glass in a greenhouse, trapping the sun's heat and stopping it from leaking back into space. Many of these gases occur naturally, but human activity is increasing the concentrations of some of them in the atmosphere, in particular:

- Carbon dioxide ($CO_2$)
- Methane ($CH_4$)
- Nitrous oxide ($N_2O$)
- Water Vapour ($H_2O$)
- Tropospheric ozone (O3)
- Chlorofluorocarbons (CFCs)

**Main greenhouse gases**

Carbon dioxide ($CO_2$) is a minor but very important component of the atmosphere; carbon dioxide is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Humans have increased atmospheric $CO_2$ concentration by more than a third since the Industrial Revolution began. This is the most important long-lived "forcing" of climate change. $CO_2$ is the greenhouse gas most commonly produced by human activities and it is responsible for 64% of man-made global warming. Its concentration in the atmosphere is currently 40% higher than it was when industrialization began.




Atmospheric carbon dioxide ($CO_2$) concentration has risen from pre-industrial levels of 280 parts per million by volume (ppmv) to over 401 ppmv in 2016. Since 1959 alone (shown here), concentrations have risen by more than 85 ppmv. The yearly rise and fall in the chart reflects the growth and decay or northern hemisphere vegetation.

Methane is a hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture, and especially rice cultivation, as well as ruminant digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, methane is a far more active greenhouse gas than carbon dioxide, but also one which is much less abundant in the atmosphere. Methane is responsible for 17% of man-made global warming.

Nitrous oxide is a powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning. Nitrous oxide is responsible for 6% of the global warming.

**Other greenhouse gases**

Water vapor is the most abundant greenhouse gas, but importantly, it acts as a feedback to the climate. Water vapor increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect.

Tropospheric ozone ($O_3$), which also has a short atmospheric lifetime, is a potent greenhouse gas. Chemical reactions create ozone from emissions of nitrogen oxides and volatile organic compounds from automobiles, power plants, and other industrial and commercial sources in the presence of sunlight. In addition to trapping heat, ground-level ozone is a pollutant that can cause respiratory health problems and damage crops and ecosystems.

Chlorofluorocarbons (CFCs) are synthetic compounds entirely of industrial origin used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer. They are also greenhouse gases.

**Causes and consequences of rising emissions**

On Earth, human activities are changing the natural greenhouse. Over the last century the burning of fossil fuels like coal and oil has increased the concentration of atmospheric carbon dioxide ($CO_2$). This happens because the coal or oil burning process combines carbon with oxygen in the air to make $CO_2$. To a lesser extent, the clearing of land for agriculture, industry, and other human activities has increased concentrations of greenhouse gases. The causes are as follow:

- Burning coal, oil and gas produces carbon dioxide and nitrous oxide.
- Cutting down forests (deforestation). Trees help to regulate the climate by absorbing $CO_2$ from the atmosphere. So when they are cut down, that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding to the greenhouse effect.
- Increasing livestock farming. Cows and sheep produce large amounts of methane when they digest their food.
- Fertilizers containing nitrogen produce nitrous oxide emissions.
- Fluorinated gases produce a very strong warming effect, up to 23 000 times greater than $CO_2$.

The consequences of changing the natural atmospheric greenhouse are difficult to predict, but certain effects seem likely:

- On average, Earth will become warmer. Some regions may welcome warmer temperatures, but others may not.
- Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer.
- A stronger greenhouse effect will warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing further to sea level rise.
- Meanwhile, some crops and other plants may respond favorably to increased atmospheric $CO_2$, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities.

**2. Global warming**

The current global average temperature is 0.85°C higher than it was in the late $19^{th}$ century. Each of the past three decades has been warmer than any preceding decade since records began in 1850.

An increase of 2°C compared to the temperature in pre-industrial times is seen by scientists as the threshold beyond which there is a much higher risk that dangerous and possibly catastrophic changes in the global environment will occur. For this reason, the international community has recognized the need to keep warming below 2°C.

The extent of global warming in the future is wrapped in uncertainty; first, because we have no idea of how much of an increase to expect in greenhouse gases (depending on economic growth), and secondly, because we do not know exactly how our climate system will respond (climate sensitivity).

3. **Deforestation**

Plants play an important role in regulating the climate because they absorb carbon dioxide from the air and release oxygen back into it. Forests and bushland act as carbon sinks and are a valuable means of keeping global warming to 1.5°C.

But humans clear vast areas of vegetation around the world for farming, urban and infrastructure development or to sell tree products like timber and palm oil. When vegetation is removed or burnt, the stored carbon is released back into the atmosphere as $CO_2$, contributing to global warming. Up to one-fifth of global greenhouse gas pollution comes from deforestation and forest degradation.

## Section 2 - Impacts of Climate Change on People and Environment (social economic and environment)

This section examines the various impacts that climate change has on the lives of the masses and how it endangers their means of livelihood and way of living.

### 2.1. Introduction to Climate Change Impacts

The climate change impacts are being felt all over the world with ecosystems and human communities all being affected equally. These impacts extend well beyond just an increase in temperature. The basic everyday elements of our life such as water, energy, wildlife, agriculture, transportation and human health are under threat from climate change impacts.

Following are some of the major climate change related impacts which are being witnessed all over globe.

1. **Water**

Water provides vital services for nature, agriculture and nearly all sectors of society. Ground and surface waters are the primary source for drinking water supply. Rivers are used for transport and play important roles in energy supply, providing hydropower and cooling water for thermal power plants.

Climate change is having serious impacts on the world's water systems through more flooding and droughts. Warmer air can hold a higher water content, which makes rainfall patterns more extreme.

Rivers and lakes supply drinking water for people and animals and are a vital resource for farming and industry. Freshwater environments around the world are already under excessive pressure from drainage, dredging, damming, pollution, extraction, silting and invasive species. Climate change only exacerbates the problem and makes this worse. Extremes of drought and flooding will become more common, causing displacement and conflict.

In mountainous regions, melting glaciers are impacting on freshwater ecosystems. Himalayan glaciers feed great Asian rivers such as the Yangtze, Yellow, Ganges, Mekong and Indus. Over a billion people rely on these glaciers for drinking water, sanitation, agriculture and hydroelectric power.

### 2. Agriculture and forestry

Agriculture is the basis for our food supply and, with forestry, increasingly also for other commodities for a bio based economy. Cereals and potatoes provide our staple food, vegetables and fruits provide fibers and vitamins, feed crops provide (supplementary) animal nutrition for cattle and poultry which in turn provide animal proteins in human diets. First generation biofuels are produced from maize, sugar and oil crops, though more modern biofuels increasingly use crop residues. Forest products are used for construction, paper and energy supply. Though heavily influenced by socioeconomic drivers (e.g. the European Common Agricultural Policy) agricultural productivity is still susceptible to weather extremes and climate trends.

These climate trends may affect agricultural systems in a number of ways. Changes in temperature may lead to changing growing season lengths with implications for cropping calendars e.g. high spring/summer temperature may lead to too early seed maturation leading to reduced yields. Summer droughts may further negatively impact yields (for e.g. the 2003 European heat wave). Early germination may increase the risks of frost damage. More frequent extreme precipitation may also lead to damaged crops. High temperatures especially when combined with high humidity may increase the risk of pests. Changing weather patterns (e.g. temperature, and rain) call for new agricultural techniques and practices adjusted to changes in local climatic conditions. Climate change will alter the suitability of regions for certain forest types and affect forest composition.

### 3. Energy

The increase in temperature will likely increase our energy demand, as well as change our ability to produce electricity and deliver it reliably. The use and production of energy have a massive impact on the climate and the converse is also increasingly true. Climate change can alter our energy generation potential and energy needs. For example, changes to the water cycle have an impact on hydropower, and warmer temperatures increase the energy demand for cooling in the summer, while decreasing the demand for heating in the winter.

**4. Wildlife**

Climate change is likely to be the greatest cause of species extinctions this century. The Intergovernmental Panel on Climate Change (IPCC) says a 1.5°C average rise may put 20-30% of species at risk of extinction. If the planet warms by more than 3°C, most ecosystems will struggle.

Many of the world's threatened species live in areas that will be severely affected by climate change. It is also happening too quickly for many species to adapt. Wildlife such tigers, snow leopards, Asian rhinos, orangutans, polar bears and Adélie penguins are the most vulnerable of species due to climate change.

**5. Health**

Climate change will have both direct and indirect effects on human health. Direct effects result from, for example, changes in the intensity and frequency of extreme weather events. Indirect effects can be felt through changes in the incidence of diseases transmitted by insects (mosquitoes and ticks) or changes in water and air quality. The health impacts can be listed as morbidity and mortality, water related issues, air quality, ultraviolet radiations, mental diseases. Some of the diseases with the largest environmental contribution in DALYs in decreasing order are diarrhea (38%), lower respiratory infection (25%), other unintentional injuries (14%), malaria (12.5%), road traffic injuries (10%) and chronic obstructive, pulmonary disease (8%).

## Explain how climate impacts are discerned

Climate impact changes can be understood through different ways such as the change in weather patterns, global warming, an increase in sea levels and unpredictable rainfalls and droughts.

These impacts are linked with a host of other processes and are not isolated. For example, if the soil in a certain area is dry that would lead to less vegetal cover. Over time soil erosion will increase giving rise to sedimentation and a decrease in the fish production levels. Subsequently, this would reduce the food security of any certain area. Food security can also come under threat due to variable rainfall. If the rainfall in a certain area is recorded to be high over a given period, it can lead to a less robust rainfed agriculture system which would lead to decreased food security.

In order to discern the human influence on climate, scientists must consider many natural variations that affect temperature, precipitation, and other aspects of climate from local to global scale, on timescales from days to decades and longer. One natural variation is the El Niño Southern Oscillation (ENSO), an irregular alternation between warming and cooling (lasting about two to seven years) in the equatorial Pacific Ocean that causes significant year-to-year regional and global shifts in temperature and rainfall patterns. Over hundreds of thousands of years, slow, recurring variations in Earth's orbit around the Sun, which alter the distribution of solar energy received by Earth, have been enough to trigger the ice age cycles of the past 800,000 years.

Scientists have made major advances in the observations, theory, and modelling of Earth's climate system; and these advances have enabled them to project future climate change with increasing confidence. Nevertheless, several major issues make it impossible to give precise estimates of how global or regional temperature trends will evolve decade by decade into the future. Firstly, we cannot predict how much $CO_2$ human activities will emit, as this depends on factors such as how the global economy develops and how society's production and consumption of energy changes in the coming decades. Secondly, with current understanding of the complexities of how climate feedbacks operate, there is a range of possible outcomes, even for a particular scenario of $CO_2$ emissions. Finally, over timescales of a decade or so, natural variability can modulate the effects of an underlying trend in temperature. Taken together, all model projections indicate that Earth will continue to warm considerably more over the next few decades to centuries.

## Section 3: Responses to Climate Change - Mitigation and Adaptation

IPCC defines mitigation as 'a human intervention to reduce the sources or enhance the sinks of greenhouse gases.'

Also according to the IPCC, the definition of adaptation is 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.'

There are several ways to mitigate and adapt to the changing climate that we witness. Given below are some areas which need to be addressed in order to ensure climate change adaptation.

### 3.1. Climate Change and Forest Management

Forest management can be divided into three main approaches. They are emission avoidance, sequestration and substitution.

1. **Emission avoidance**

Prevent carbon from being emitted into the atmosphere. This can be done by avoiding burning trees and grasses as they are composed of carbon; burning them produces greenhouse gases. Cultivating the soils after deforestation further contributes to climate change and cultivation oxidizes 25-30% of the organic matter in the upper meter of soil and releases carbon dioxide to the atmosphere. Forests also emit greenhouse gases to the atmosphere when they are logged. The trees are harvested end up as wood products, so the majority of the forest vegetation ends up as waste and as that waste decays, carbon is released into the atmosphere. Planting trees and restoring forests reverses the flux of carbon in the cycle, withdrawing carbon from the atmosphere and accumulating it again in the soils and vegetation through photosynthesis.

It can be avoided by instituting and enforcing policies to address drivers of deforestation and degradation and carefully managing fire, drought, disease, and invasive species.

2. **Sequestration**

The second important strategy for forest management is carbon sequestration. It is the use of management in forest ecosystems to sequester additional carbon. Forest management actions to increase carbon storage are control fire, pests, and disease, increase forest growth, control competition, enhance regeneration, fertilization, select for improved/superior stock and manage for higher C stocks in stands.

3. **Substitution**

A third general way that forest management can mitigate climate change is through the use of wood (from production forests) as a substitute for fossil fuels (energy production) or building materials. Woods and other forest products used in construction store more carbon, emit less GHGs, and use less fossil energy. Manufacturing and construction using materials e.g. steel, concrete, brick, or vinyl is energy intensive and produces substantial emission. However, life cycle analysis to assess carbon accounting from forest through utilization phases is crucial in order to make an appropriate decision

## 3.2. Climate Change and Water Resources: Responses and Adaptation

The impacts of climate change on water resources can be recognized by more rain and increasing floods in winter, as well as early melting of snow from glaciers, and lower summer stream flows.

In order to respond to the climate change impacts on water resources, climate adaptive actions should be taken. Climate adaptive actions are all those actions that protect and restore water and watersheds.

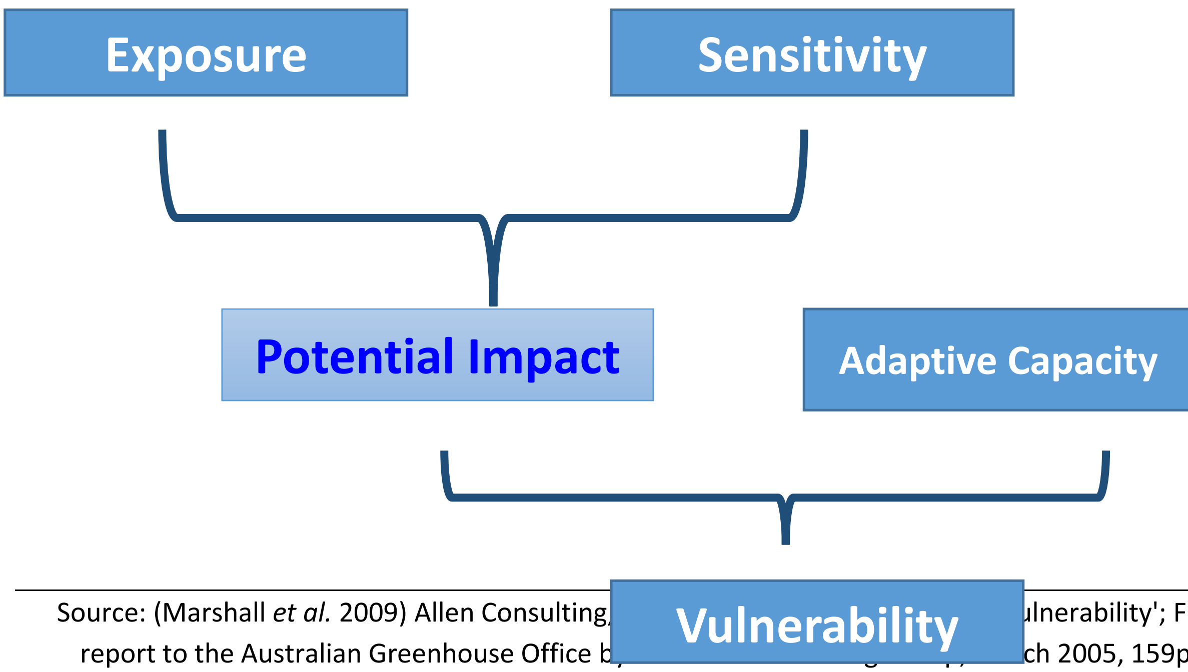
Forests should be managed to reduce impacts to water and watershed functions, use controlled fire where possible to reduce fuel buildup and the potential for large catastrophic fires and subject all land use to low impact land use planning. Conduct vulnerability assessment to set priorities and inform decisions and overlay results with existing strategies, constraints and opportunities to set priorities.

The most important area for climate adaptation can be agriculture. Introduction of drip irrigation in fields, improving rain fed farming, shift cropping patterns and crops, and expand urban farming. Crops need to be improved for drought resistance, selection of the best crop for suitable land and plant shorter rotation crops.

## 3.3 Climate Change Vulnerability

Vulnerability to climate change is the degree to which these systems are susceptible to, and unable to cope with, adverse impacts. Vulnerability of ecosystems and species is partly a function of the expected rapid rate of climate change relative to the resilience of many such systems.

**Components of Vulnerability**




Source: (Marshall *et al.* 2009) Allen Consulting, ... ulnerability'; Final report to the Australian Greenhouse Office b... ch 2005, 159pp

**Why do we assess vulnerability?**

Assessing vulnerability is of utmost importance due to various reasons. Vulnerability assessment is done in order to contribute to climate-aware land-use planning and to understand the implications and impacts of rapid climate change. It is a vital factor in promoting resilience and is essential for setting priority areas for adaptation. It helps in designing adaptive responses and ensures focus on research and monitoring.

Vulnerability assessment also helps in answering a number of questions such as which places are more vulnerable and prone to disaster. It highlights weak and strong points and indicates which places are more resilient than others. Conflicts in any place do not arise all of a sudden. They are the outcomes of several years of negligence and oversight. This assessment helps in better understanding where the conflicts will arise first and what will be the worst among them.

A basic vulnerability assessment model is given below. It constitutes low and high sensitivity levels and values and places them on a matrix table with the corresponding values.

| | **Low Sensitivity** | **High Sensitivity** |
|---|---|---|
| **Low Values** | **No Worries** | **Watch** |
| **High Values** | **Refugia** | **Priority** |

Source: MJ Furniss

**How to assess Vulnerability?**

Following seven criteria are important to identify the key vulnerabilities in any given situation.

1. Magnitude
2. Timing
3. Persistence & Reversibility
4. Likelihood
5. Potential for Adaptation
6. Distribution
7. Importance of the system

**Resilience**

In ecology, resilience is the capacity of an ecosystem to response to a disturbance by resisting damage and recovering quickly. According to IPCC, resilience is defined as "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation."

## 3.4 Ecosystem Services

Ecosystem services are the multiple benefits provided to human society by the ecosystems. Ecosystem services are a way of accounting for and communicating about the things we get from natural systems; the things that we value from nature, from forests and rivers, air, soil, water, wildlife and solitude.

Ecosystems provide essential services on which humans depend such as provisioning services, regulating services, supporting services and cultural services.

The provisioning services can be explained as food, fresh water, timber, wood and fiber, genetic resources, medicines. Regulating services are numerous such as climate, air quality, water, disease regulation, pest control and pollination. The supporting services cater to the processes necessary for proper functioning of other services, such as provision of habitat, primary production, soil formation and nutrient cycling. The final kind of services is cultural services. They could be educational, aesthetic beauty, cultural heritage, recreation, spiritual and religious values and tourism.

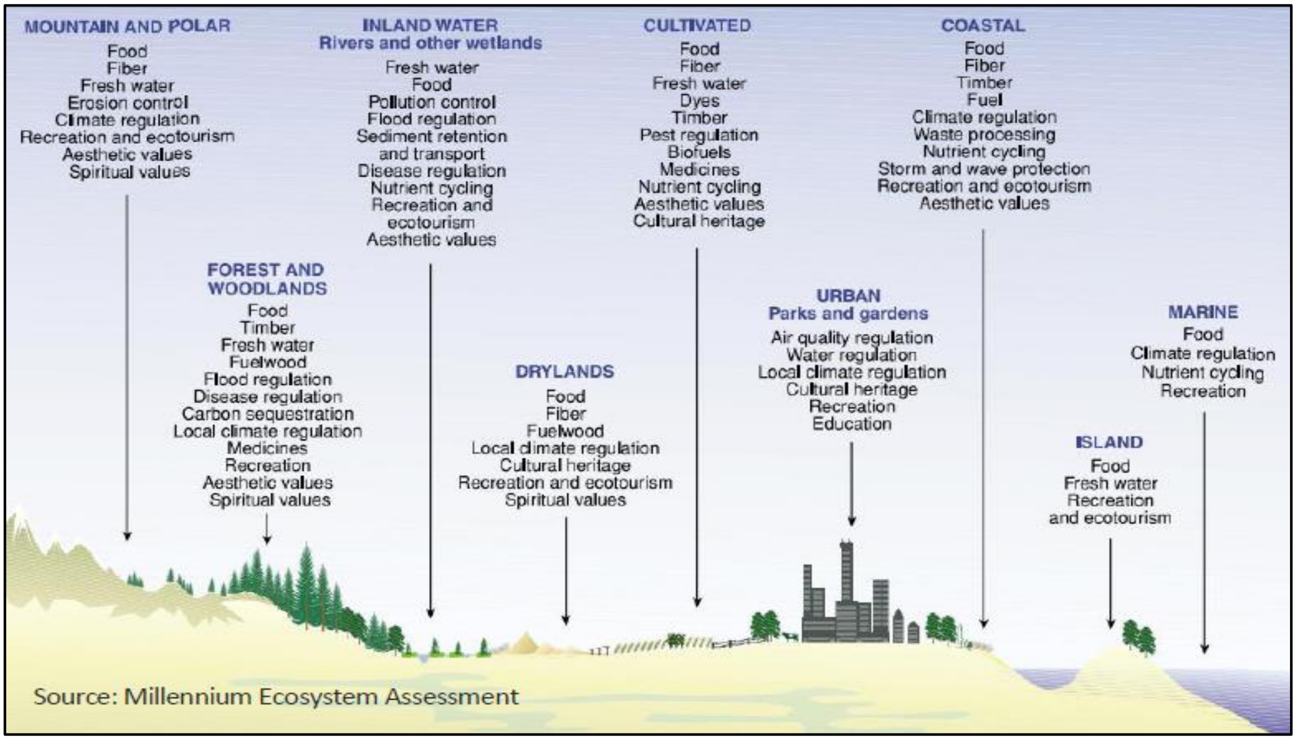
**Conditions and trends of ecosystem services**

Different conditions and trends prevail in the ecosystem services. The provisioning services discussed above such as food, fresh water, timber, wood are prone to changes due to climate change related factors. Water resource scarcity is a real phenomenon and a number of countries and regions are experiencing acute shortage. High level of arsenic amount found in water as well as high concentration of pollutants and declining water availability all are indicators of changes in ecosystem.

The same distressing trends can be seen in the rest of the three ecosystem services. Regulating services may face declining farmland productivity; soil erosion; high salt accumulation in soil and declining water quality. The cultural services such as tourism, cultural heritage etc. are disturbed in several ways such as disturbing landscapes; declining non-recreational cultural services and adding to the decreasing numbers in tourism. The support services which are under threat could be declining biological productivity and losing wildlife habitats.

**Payments for ecosystem services**

The incentives offered to farmers or landowners in exchange for managing their land to provide some sort of ecological service are known as payments to ecosystem services. They have been defined as "a transparent system for the additional provision of environmental services through




conditional payments to voluntary providers." (Tacconi, L. (2012)

## 3.4 Climate Change communication

The process of transmission and sharing information on the causes and impacts of climate change; and response measures (both mitigation and adaptation) to climate change in order to raise awareness, influence attitude and change behavior. On the surface, climate change communication is about educating, informing, warning, persuading, mobilizing and solving this critical problem. At a deeper level, climate change communication is shaped by our different experiences, mental and cultural models, and underlying values and worldviews.

**Effective communication in climate change**

Climate change is the most pressing issue of the 21st century and needs the utmost attention of policy makers and the relevant stakeholders. Our action or inaction on climate policy today will continue to reverberate, for better or worse, far into the future. What those social science insights tell us is that it is possible to communicate climate science in a way that makes that message easier for non-scientific audiences to understand, and makes it more relevant to their lives and experiences. Connecting with your audience on the basis of shared values builds trust between the communicator and the audience.

To effectively build and implement mitigation, adaptation & disaster risk reduction strategies which in turn influence national policies, engage other sectors and integrate traditional knowledge into scientific research. Climate change information must be actively communicated with appropriate language, made vivid through visual imagery and experiential scenarios, balanced with scientific information. Gaining public support for climate change policies and encouraging environmentally responsible behavior depends on a clear understanding of how people process information and make decisions. There is no "one size fits all" approach. Ensuring that people feel both a personal connection with climate change and a desire to take action to mitigate its impact is key. People need to know that there are solutions that they can be a part of.

**Communication Principles**

In total, there are six climate change communication principles that are discussed in this section. They are succinctly discussed below.

1. **Know your audience**

   The first principle is to be aware of the values and norms of the people that one is trying to talk to. To select message aims that will resonate with the audience and set goals which are attainable. Knowledge of the target audience is essential as it helps in understanding their local concerns, what people already are doing; what actions are people willing to take. The communicator should come across as a friendly guide instead of a strict instructor. This helps to validate the audience, affirm their sense of self, appreciate past accomplishments, speak to what they care about sympathize with their struggles and concerns and connect climate action to something they already do. Knowing your audience is important in designing messages and selecting modes of communication for an effective communication program. It helps to reduce barriers and promote behavior change.

2. **Translate scientific data into concrete experience**

The social science evidence shows that experiential processing is a stronger motivator for action, but most climate change communication remains geared toward the analytical processing system. Personal or anecdotal accounts of climate change experiences, which could easily outweigh statistical evidence, are rarely used. The use of vivid imagery such as videos, metaphors, stories is critical to make the audience understand the true damage that climate change can cause. It is imperative to avoid jargon especially scientific terms and acronyms because people are confused by them. The use of non-technical language can help the audience to better understand the threat of climate change.

3. **Beware of overuse of emotional appeals**

The overuse of emotional appeals in climate change messages and communications can prove to be counter-productive. Emotional appeals can get attention early on but can be challenging later on with results difficult to reverse. Modern life tends to be busy with people constantly multi-tasking and worrying about a lot of things at one time becomes difficult. People have limited capacity to worry so it is suggested to not overdo the messages as people also have short attention spans. The tendency of taking one action even if it is not the most effective one is known as single action bias. We have a tendency to focus and simplify our decision making when responding to a threat we may take one action even if it is not the most effective one. We often take no further action because we presume the first one worked.

4. **Acknowledge Scientific and Climate Uncertainties**

We will never have 100% certainty/confidence but we can make predictions based on the best available data, quantifying uncertainties associated with those predictions. As humans we have a need for predictability, uncertainty can be uncomfortable. Climate science often conveys the mistaken impression that as scientists we may be confused, when in reality scientific uncertainties about how much warmer the planet will be in 100 years doesn't change the very high confidence scientists have that human-made GHGs are warming the planet and will continue to do so. People may understand probabilistic information better when presented to a group, where there is the opportunity to discuss with a range of knowledge, skills and personal experience to share diverse perspectives and work together to problem solve. Group discussions allow for a greater chance that multiple sources of information – both experiential and analytic – will be considered in climate change decision-making processes. People devote more energy to implementing solutions after participating in group discussion. Whenever possible, present climate change information to informal groups where people are free to ask questions and discuss with the speaker and each other.

**5. Connect to social identities and affiliations**

In order to promote better decision making, participatory decision making should be encouraged. Stakeholders who feel like they are a part of the decision-making process are more likely to support the outcome. Encourage early participation in the decision-making process to ensure that the group identifies key problems that require solutions. Also leave ample time for discussion so that the participants are able to absorb the dense and complicated information. Breaking large groups into smaller groups can help initiate discussion on a more personal level and encourage people who might be hesitant to speak out in large groups to contribute to the discussion.

**6. Make Behavior Change Easier**

It is human tendency to stick with the option that is selected automatically instead of choosing an alternate option. Take advantage of this to encourage audiences to make changes in their behavior that will help mitigate effects of climate change**.** When making decisions about consumption, people tend to be more patient when the default option is to receive something now. Because the default option requires no action, it is always easier, and so people tend to accept it whether or not they would have chosen it if it were not the default option. Giving people an immediate incentive, if possible, makes behavior change easier.

## Glossary

**Adaptation -** Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

**Aerosols** - A collection of airborne solid or liquid particles, typically between 0.01 and 10 µm in size and residing in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in several ways: directly through scattering and absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds.

**Biodiversity** - The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

**Biofuel** - Any liquid, gaseous, or solid fuel produced from plant or animal organic matter for example soybean oil, alcohol from fermented sugar, black liquor from the paper manufacturing process, wood as fuel, etc. Second-generation biofuels are products such as ethanol and biodiesel derived from ligno-cellulosic biomass by chemical or biological processes.

**Biomass** - The total mass of living organisms in a given area or of a given species usually expressed as dry weight. Organic matter consisting of, or recently derived from, living organisms (especially regarded as fuel) excluding peat. Biomass includes products, by-products and waste derived from such material.

**Carbon dioxide ($CO_2$)** - $CO_2$ is a naturally occurring gas, and a by-product of burning fossil fuels or biomass, of land-use changes and of industrial processes. It is the principal anthropogenic greenhouse gas that affects Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore it has a Global Warming Potential of 1.

**Carbon intensity** - The amount of emissions of $CO_2$ per unit of GDP.

**Chlorofluorocarbons (CFCs)** - Greenhouse gases covered under the 1987 Montreal Protocol and used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. Because they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone.

**Climate Change (CC)** - Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

**Deforestation** - The natural or anthropogenic process that converts forest land to non-forest.

**Ecosystem** - A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study.

**Emissions** - In the climate change context, emissions refer to the release of greenhouse gases and/or their precursors and aerosols into the atmosphere over a specified area and period of time.

**Forecast** – Projected outcome from established physical, technological, economic, social, behavioral, etc. patterns.

**Forest** – Defined under the Kyoto Protocol as a minimum area of land of 0.05-1.0 ha with tree-crown cover (or equivalent stocking level) of more than 10-30 % with trees with the potential to reach a minimum height of 2-5 m at maturity in situ. A forest may consist either of closed forest formations where trees of various story and undergrowth cover a high proportion of the ground or of open forest.

**Fossil fuels** – Carbon-based fuels from fossil hydrocarbon deposits, including coal, peat, oil and natural gas.

**Global warming** – Global warming refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.

**Greenhouse effect** – Greenhouse gases effectively absorb infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect.

**Greenhouse gases (GHGs) -** Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapour ($H_2O$), carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$) and ozone ($O_3$) are the primary greenhouse gases in the earth's atmosphere.

**Hydrofluorocarbons (HFCs) -** One of the six gases or groups of gases to be curbed under the Kyoto Protocol. They are produced commercially as a substitute for chlorofluorocarbons. HFCs are largely used in refrigeration and semiconductor manufacturing. Their Global Warming Potentials range from 1,300 to 11,700.

**Landfill –** A landfill is a solid waste disposal site where waste is deposited below, at or above ground level. Limited to engineered sites with cover materials, controlled placement of waste and management of liquids and gases.

**Methane ($CH_4$) -** Methane is one of the six greenhouse gases to be mitigated under the Kyoto Protocol. It is the major component of natural gas and associated with all hydrocarbon fuels, animal husbandry and agriculture.

**Mitigation –** Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks.

**Nitrous oxide ($N_2O$) -** One of the six types of greenhouse gases to be curbed under the Kyoto Protocol.

**Ozone ($O_3$) -** Ozone, the tri-atomic form of oxygen, is a gaseous atmospheric constituent. In the troposphere, ozone is created both naturally and by photochemical reactions involving gases resulting from human activities.

**Perfluorocarbons (PFCs) -** Among the six greenhouse gases to be abated under the Kyoto Protocol. These are by-products of aluminum smelting and uranium enrichment. They also replace chlorofluorocarbons in manufacturing semiconductors. The Global Warming Potential of PFCs is 6500–9200.

**Renewables -** Energy sources that are, within a short timeframe relative to the earth's natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind.

**Sensitivity** - The degree to which a system will respond to a given change in the climate

**Sequestration –** Carbon storage in terrestrial or marine reservoirs. Biological sequestration includes direct removal of $CO_2$ from the atmosphere through land-use change, afforestation, reforestation, carbon storage in landfills and practices that enhance soil carbon in agriculture.

**Sulphur hexafluoride ($SF_6$) -** One of the six greenhouse gases to be curbed under the Kyoto Protocol. It is largely used in heavy industry to insulate high-voltage equipment and to assist in the manufacturing of cable-cooling systems and semi-conductors. Its Global Warming Potential is 23,900.

**Vulnerability** - The extent to which climates change may damage or harm a system, depending not only on the system's sensitivity but also its capacity to adapt to the given change.