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# Global Warming: Evidence, Causes, Consequences and Mitigation

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## ABSTRACT

Studies suggest that rise in the global temperature since 1880 (estimated 0.8 to 1.0oC) is real and considerably alarming. Although natural causes have been responsible for repeated global temperature changes in the geological past, the present rise is commonly attributed to the concentration of anthropogenic greenhouse gases, mainly carbon dioxide (CO2), in the atmosphere. CO2, which takes hundreds of years to be removed from the atmosphere, has increased significantly over the past century. Increasing consumption of fossil fuels in energy production, industry, transport, agriculture and other human activity has been causing the emission of greenhouse gases in the Earth's system. More than 2°C increase in temperature by the end of this century would be severe if not catastrophic. Global warming would result in melting of glaciers and polar icecaps, water depletion, insecurity of food, sea-level rise and threat to coastal regions, coral reefs extinction, migration of species and natural disasters. The potential threats of climate change are assumed to be more severe to the less developed countries because of their lack of resilience and preparedness. The situation, according to some, is desperate and urgently requires remedial steps such as removal of CO2 from atmosphere, afforestation, use of clean energy, and changing our life style to control Earth's temperature. The world needs

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to unite in taking necessary remedial steps on an urgent basis to ensure sustainable development.

**Keywords**: Global warming, GHG emissions, clean energy, carbon capture, Solar Radiation Management.

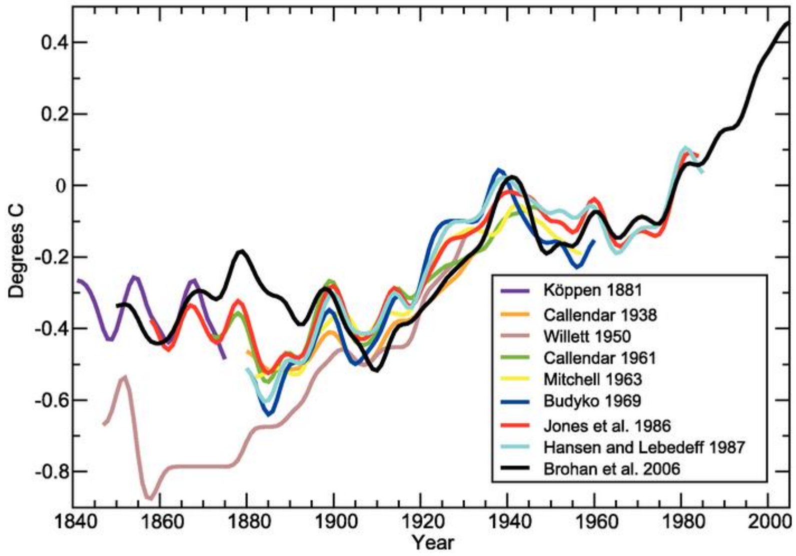
## 1. INTRODUCTION

Global climate has not remained constant. There have been temperature variations over long to short time intervals, resulting entirely from natural causes. The geologic history of Earth shows severe drops in temperature, followed by interglacial periods of normal and warm temperatures, as shown by widespread glaciations and sea-level change records in sediments. Faunal extinctions, such as the disappearance of dinosaurs some 65 million years ago, could also be attributed to severe climate changes (Ceballos et al. 2015).

The growing concern expressed by climate scientists over global warming since the 1980s was prompted by the general perception that the rise in global temperature observed during the second half of the 20th century is due to human factors and is likely to disrupt the planetary climate system with profound negative impact on ecosystems and human wellbeing. Climate scientists pointed out that the rise in surface temperature had been caused by the unprecedentedly large scale emissions of CO2 and other greenhouse gases (GHG) from the burning of fossil fuels for producing energy since the Industrial Revolution, and widespread deforestation and forest degradation. The UN-sponsored Inter-governmental Panel on Climate Change (IPCC), established in 1987 to examine the scientific evidence related to climate change, confirmed the consensus among climate experts in its First Assessment Report (FAR) issued in 1990. In light of the FAR, the inter-governmental negotiations convened by the UN General Assembly culminated in the adoption of the UN Framework Convention on Climate Change (UNFCCC) in 1992. The Paris Agreement, adopted in December 2015, is meant to implement the UNFCCC.

According to the Fifth Assessment Report (AR5) of the IPCC issued in 2013-2014, global temperature has risen by about 0.8oC over the past 130 years, 50% of which was in the past 35 years (Wolff and Fung 2014). Temperature records show that the global average temperature in the 20th century was 13.9°C with a rise of 0.99°C by 2016 (NASA 2017). The 12 warmest years on record have occurred since 1998 and every one of the past 38 years has been warmer than the 20th century average. According to the US National Oceanic and Atmospheric Administration (NOAA), the three consecutive years 2014, 2015, and 2016 have shown record breaking heat all over the planet, with 2016 as the hottest year of the century (Plait 2017). Sea-level has risen by 20cm over the previous century. A rise of 2°C would be severe, and 4°C (feared by some for the end of this century) would be disastrous (EPAa 2016). Interestingly, increase in the global temperature has not occurred steadily but at irregular intervals. Typical features of the temperature are a distinct warming trend from 1910 to 1940 followed by the sharp warming trend until the end of the 20th century. Figure 1 shows variation in global temperature for 160 years period (1840-2000). There is a marked increase in temperature during the 20th century in all reported data sources.

**Figure1:** Published records of surface temperature change with time over large regions




*Source: IPCC (2007)*

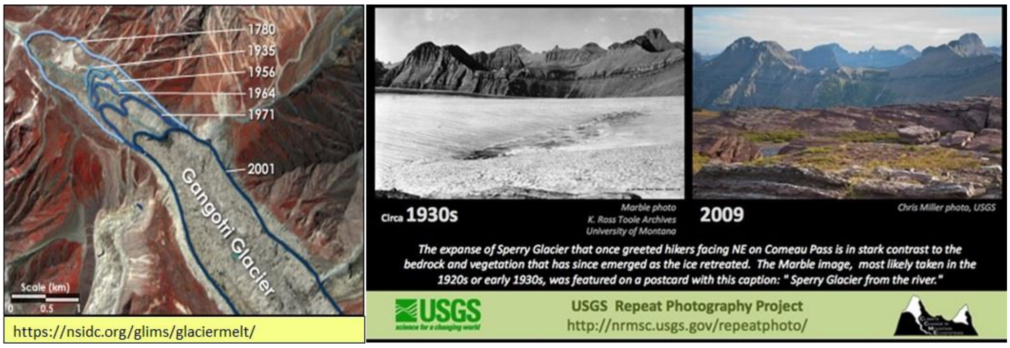
## 2. EVIDENCES FOR GLOBAL WARMING

Several lines of evidence corroborate rise in global surface and ocean temperature. All heat measurement records, 1) over oceans (measurement data to 1850), 2) of heat content of the oceans (it has been argued that >90% of the extra heat from global warming is transferred to oceans), 3) on continents (weather stations), and 4) near surface (troposphere 50 years satellite data) show increasing temperature trends. Additional supporting evidence is provided by 5) rise in sea-level, 6) increase in humidity, 7) recession in glaciers and reduction in polar icecaps (satellite data since 1973 and reliable shipping records to 1953 showing 35% shrinking in September ice cover), 8) increased events of coral bleaching due to rise in ocean temperature (which can lead to their mortality), 9) change in birds' breeding seasons and early emergence of insects from the ground, and 10) the release of methane into the atmosphere by thawing of permafrost (Lead Pakistan n.d.). In the following sections, some of the global warming evidences are elaborated.

### 2.1. Melting and Recession of Glaciers

There are many studies that suggest recession in glaciers and the polar ice cover since 1850. The temporal coincidence of the increase in the quantity of GHG in the atmosphere and glacier retreat is commonly cited as an evidence of global warming. Tropical and subtropical mountain ranges, such as the Alps, Cascades, Rockys, and the southern Andes, have been undergoing large glacial losses (Molg 2015). Paradoxically, the 2000-2010 data on the highest mountain system (the Himalayan-Karakoram region) shows divergence. Bahuguna et al. (2014) reported that 2026 of the Himalayan-Karakoram glaciers during the 10-year period underwent only 2% shrinking in area. They also noted that the longest glacier of the region, Siachin in the Karakoram, remained stable during this period. It has been observed that whereas the Himalayan glaciers (fed mostly by monsoons) have been receding, the western Karakoram glaciers (fed mostly by westerlies) have remained stable. NASA footage of the Bhutan Himalayan glaciers shows that they have been receding over the past few decades, resulting in the formation of lakes, some leading to glacial lake outbursts. Gangotri, the largest Himalayan glacier (Figure 2 left), has receded by 850 m (NSIDC 2017). Glacial recession has taken place in other parts of the world also. Figure 2 (right) shows substantial reduction of ice cover in the Sperry Glacier of Montana, USA, over eight decades.

**Figure 2:** Images of recession in Gangotri Glacier, Himalaya (left) and Sperry Glacier, Montana (right).




*Sources: NSIDC (2017) and USGS (n.d.)*

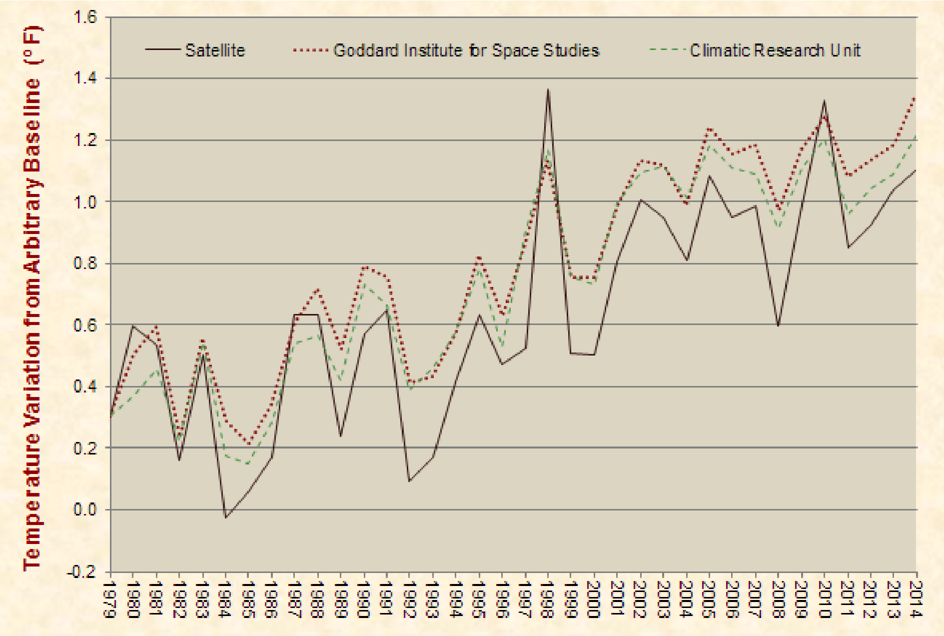
## 2.2. Melting of Polar Ice Caps and Reduced Snowfall in the Northern Hemisphere

Both the Antarctica and Arctic ice covers have been shrinking. In 1980, Arctic ice (8 million km2) made up 2% of the Earth’s surface; now it is only a quarter of that during the summer. Antarctica has been losing about 134 billion metric tons of ice per year since 2002. This rate could speed up if the burning of fossil fuels persists at the current pace (EPAa 2016).

## 2.3. Temperature Records of Land and Ocean Water

Recorded data on temperature of the land and ocean, as well as the temperature simulation models, show an increase in global temperature between the time period of 1979 to and 2014 (Figure 3). There are some discrepancies in the simulations and actual recorded data. Temperature changes recorded for the lower tropical (20°S–20°N) troposphere between 1979 and 2008 are much smaller than what is predicted by the present climate models (Santer et al. 2008). However, even a small, steady rise in global temperatures cannot be taken lightly.

**Figure 3:** Comparison of three different average annual temperature measurements




*Source: NSSTC and NOAA (2015)*

According to the very first climate simulations made almost a quarter of a century ago (and the MPI model in Hamburg), the global warming today should rather be 1.25°C than the 0.75°-1.0°C. This is in spite of a relatively large (cooling) aerosol effect of the Hamburg model that at the time was larger than the present view of IPCC today. The tropics are a crucial area where the greenhouse effect is the largest. The data from three different sources presented in Figure 3 show almost the same measurement patterns of average annual temperature increase from 1979 to 2014.

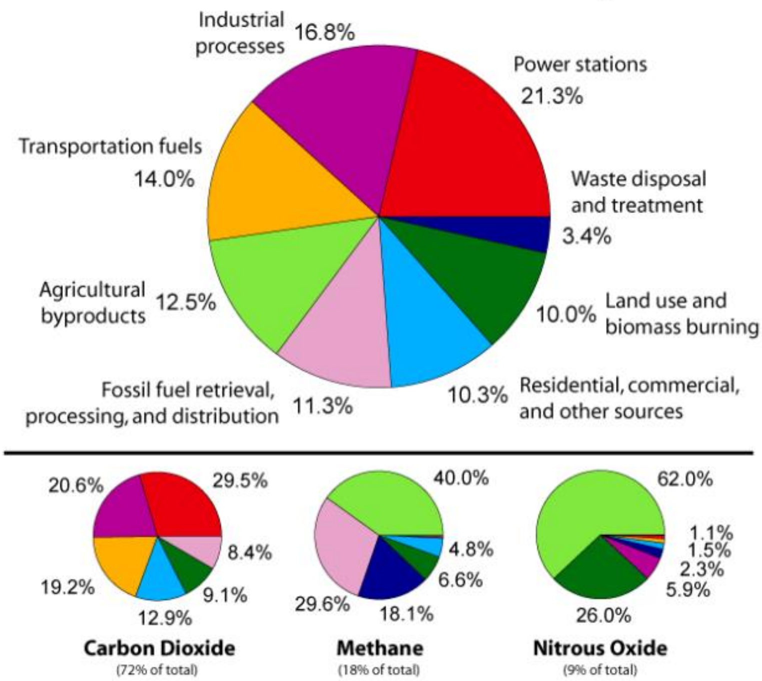
## 3. CAUSES OF GLOBAL WARMING

As mentioned above, there is ample evidence that natural processes drive climate and practically all kinds of extreme weather have always been part of the climate scenario. One theory suggests that galactic cosmic radiation modulated by solar activity affects low level cloud cover and is causing the global warming. But it would be illogical to think that the large quantities of GHG added to the atmosphere (CO2 from fossil fuel burning and gasoline; methane from agricultural activities, waste management, energy use, biomass burning; N2O from agriculture, including the use of fertilizers and biomass burning;

fluorinated gases from industrial processes, refrigeration, consumer products such as HFC, PFC, SF6), and deforestation would not accelerate global warming.

The addition of the increased volumes of $CO_2$ and other GHG to atmosphere have been considered by climate experts and simulation models to be the primary causes of the global warming that has occurred over the past 50 years (Oliver et al. 2015). Major sources which contribute towards GHG emissions in the air are shown in Figure 4. The amount of $CO_2$ per kWh electricity production from various sources of hydrocarbon fuels is shown in Figure 5. GHG remains in the atmosphere for different time period, ranging from a few years to thousands of years. $CO_2$ takes about 100 years for removal from atmosphere.

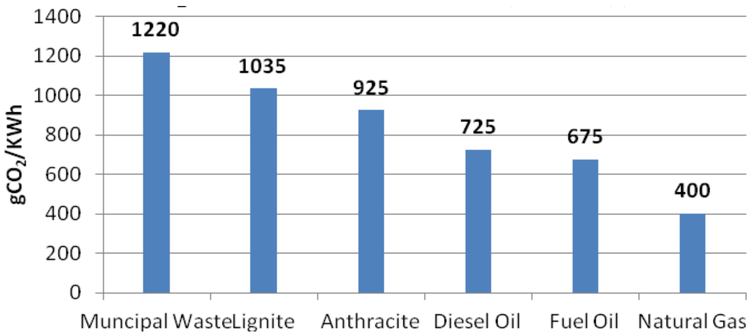
**Figure 4.** Major sources which contribute towards GHG emissions in the air




*Source: Hidalgo et al. (2008)*

Emissions from fossil-fuel combustion from various processes (industrial, i.e., production of cement clinker, metals and chemicals; transport; agriculture; etc.) is producing approximately 2.5 billion tons of $CO_2$ annually (WNA 2014). The total quantity of $CO_2$ in the atmosphere is estimated at 35.7 to 40 billion tons (Plait 2014). It has been suggested that the Earth's warming rate because of anthropogenic emissions is roughly equal to the heat that would be released by 400,000 Hiroshima A-bombs across the planet every day (Romm 2013).

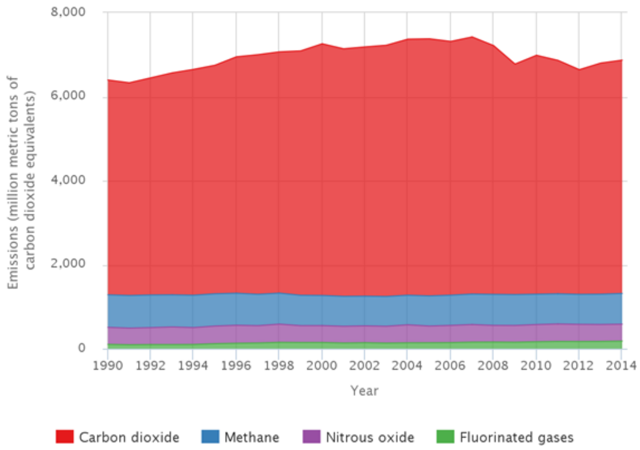
**Figure 5:** Amount of CO2 emission/kWh electricity production using various fuel sources.




*Source: IEA (2015)*

Shakun et al. (2015) reported that CO2 levels rose from about 180 ppm to 280 ppm at the end of the Ice Age, which spanned nearly 7,000 years. For centuries, the level of CO2 remained <300 ppm, however, following more than a century-and-a-half of industrialization, CO2 has now risen to approximately 400 ppm. The amount of CO2 increased in the atmosphere by 40%, and other gases, such as CH4, by a factor of 2 to 3 or more. The major contributors towards carbon emission into the atmosphere are the United States and OECD countries, China and India. Figure 6 shows the emission of various GHG in USA, estimated at 7000 million metric tons CO2 equivalent for 2014.

**Figure 6:** U.S. Greenhouse Gas Emission by Gas, 1990-2014




*Source: EPAb (2016)*

According to the IPCCC and the Paris Agreement adopted in 2015, a drastic reduction in current emission trends is urgently needed to limit a rise in average temperature to 2oC above the pre-industrial times.

## 4. CONSEQUENCES OF GLOBAL WARMING

The consequences of rising atmospheric CO2 are profound for Earth's temperatures, climate, ecosystems and biologic species, both on land and in the oceans. Changes in patterns of rainfall and snowfall, increase in drought and severe storms, reduction in ice cover, melting of glaciers and glacial lake outbursts, floods, mass movement and landslides, increase in sea levels, abnormal increase in humidity in certain parts of the world, changes in animal and plant behaviour, faunal extinction and disappearance of coral reefs have been predicted. And not without reason; faunal extinction over geological time is commonly connected to climate change. It is also obvious that global warming would impact the developing nations more severely because of their lower resilience, poor preparedness and weak economies. Climate changes would also result in mass migrations of biological species, including humans.

Global warming would adversely affect the availability of fresh water for irrigation and domestic use, forests, fishery, hydro-energy production, and mountain recreation, particularly in countries that depend on waters ensuing from glaciers. Melting of mountain glaciers, early snow melt, and resulting drought conditions would cause dramatic water shortage and seriously threaten food security and economic development in many countries of the world. Glacier melting would also result in rising sea-levels and coastal flooding, and would pose serious threat to many of the world's large cities located along the coast. High concentration of GHG in air will result in disease outbreaks such as allergies, asthma and other infectious diseases. Three of the world's most populated countries, i.e. China, Pakistan, and India, are amongst the worst five countries in terms of the air pollution (Krepon 2015).

Global rise in temperature shall have a huge impact on rivers and lakes fed by glacier and snow melt. In the greater Himalayan region (Himalaya, Karakoram, Hindu Kush, Pamir, Tibet), climate change may reduce hydro-power generation, especially in Tajikistan, the third largest hydropower generating country in the world (World Bank 2000). Agriculture is critically dependent on the waters of the mighty rivers that are fed by glacier melting in China, Pakistan, India, Central Asia and South East Asia. Pakistan's GHG emissions are less than 1% of the global emissions, but the impacts of climate change on Pakistan will be enormous in terms of rate of crop yield, variability in rainfall due to fluctuating hydrological cycles, freshwater availability, effect of heat stress and air pollution on human life, natural disasters, and so on. All these have been documented in 'National Climate Change Policy' (Ministry of Climate Change 2012).

According to the Global Climate Risk Index (German Watch 2017), Pakistan is the world's 7th most vulnerable country in terms of the negative effects of global warming and climate change accrued over the period 1996-2015.During 1996-2015, the annual average death toll induced by climate hazards was 504.75. Similarly, Pakistan faces an average annual loss of 3.8 Billion USD.

Pakistan's economy is critically dependent on agriculture and livestock sector which contributes 19.82% of GDP, employs 43.5% of labour and make up 68.5% of value added exports. Some 50% of its 145 Million acre feet (IRSA 2011) of surface water resources are recharged by glacier melt. The country has already become water-scarce as per capita water availability came down to 1,000 m3 in 2011 from 5260 m3 in 1951 (World Bank 2013). IMF (2015) placed Pakistan at 36th rank in the list of most water stressed countries. Because of water scarcity, it is experiencing drying out of wetlands and degradation of ecosystems. Moreover, water scarcity also portends alarming scenario for water-food-energy nexus (UNDP 2016). Combined with the fact that Pakistan is among the top five countries that have the least clean air (Krepon 2015), it might face a dooms day scenario. The country is technologically and economically not ready to cope with the adverse effects of climate change as observed during the 2010 flood which affected 20 million people and caused heavy damages and economic losses.

## 5. IMPACT OF GLOBAL WARMING ON SOCIO-ECONOMIC DEVELOPMENT

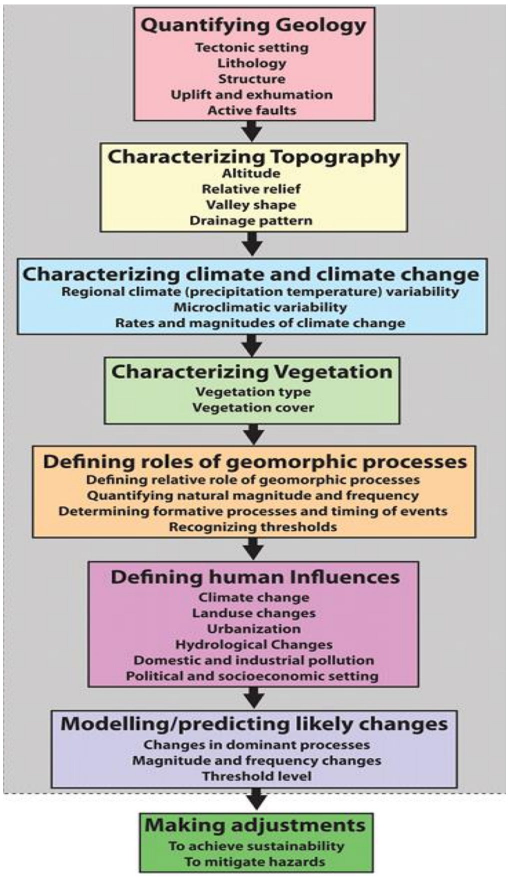
Global warming is expected to affect health, energy supply, socio economic patterns of livelihood, and living. Global warming is likely to cause approximately 20,000 heat-related deaths among the elderly in 2030 and 52,000 deaths by 2050. According to Mora (2017), almost three quarters of world's human population will be exposed to deadly climate conditions by 2100. Vector borne diseases, such as malaria, dengue, and water-related diseases, such as diarrhoea, dysentery and typhoid, are likely to re-emerge. Rising temperatures, floods, drought and limited supply of drinkable water will initiate human displacement/migration (IPCC 2014). This will not only increase the informal settlements, but would also lead to social conflicts, poverty and poor standard of life.

Climate change and sustainable development are interconnected. On the one hand climate affects socio-economic development and on the other human activity has strong effect on climate through GHG emissions and other related activities. Therefore, it is pertinent to regulate anthropogenic factors affecting climate change. In addition, a consistent and embedded approach is required to tackle continuous global warming, which is feared to cause a compounding effect on poverty, most significantly in developing countries. At many levels it is impossible to delink issues such a provision of water, energy, fisheries and agriculture from global warming and climate change (Hansen and Cramer 2015).

Developing countries need to formulate and follow policies that reduce their heavy dependence on natural resources, help them cut down the emission of GHG and help them adapt to climate variability and natural disasters. Special attention must be given to keeping a standard for recording emission levels. Detailed studies are needed to know the contribution of natural and anthropogenic processes to global warming. In order to attain our goal of keeping temperature rise under 2°C, practices like business as usual should be discouraged at national, regional and international level (Agrawal and Lemos 2015).

Mountain regions that are the abode of glaciers and ice caps are particularly vulnerable to warming. The Andes and mountains of the greater Himalayan region (Pamir, Hindu Kush, Karakoram, Himalaya and Tibet) supply large quantities of water for agriculture and domestic consumption to some 40% of the world population. Global warming would have severe impact on the supply of water, food security, forest cover, and would add to frequency and severity of natural disasters, particularly floods, mass movement, debris flow and landslides. The Himalayan region is tectonically the most active as well as the most glaciated outside the polar region, and is characterised by rapid uplift and fast erosion. Intense denudation is caused by "glacial, fluvial, landsliding, eolian and weathering processes….which change over time, influenced by topographic development, climate change and humans" (Owen, 2017). One of the most challenging aspects of future geomorphic and hazard mitigation research is to develop an accurate relationship between spatial and temporal geomorphic changes and sustainable development. In a detailed study of the geomorphic evolution of the Himalayan range, Owen (2017) proposed a comprehensive strategy, incorporating various relevant aspects, for sustainable development and geohazard mitigation in the changing global environment (Figure 7).

**Figure 7:** Process cascade for a geomorphic framework (enclosed within the grey rectangle) to help in achieving sustainable development and for hazard mitigation in Himalayan environments




*Source: Owen (2017).*

## 6. REMEDIAL MEASURES

The preceding account provides ample evidence that global warming is going to pose serious threat to the world's ecosystem. Therefore, there is an urgent need for adopting effective measures to limit increase in global warming to 2oC compared to pre-industrial levels. Paris Agreement asks for sharp reductions in the emissions and removal of GHG from the atmosphere by all possible means. There are a number of ways by which the amount of $CO_2$ in the atmosphere can be controlled (Oxford Geoengineering Programme 2017). Some are described in the following sections.

## 6.1. Replacement of Coal by Gas in Power Generation

By using climate metrics like global warming potential (GWP), global temperature change potential, technology warming potential, and cumulative radiative forcing and using Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC), Farquharson et al. (2016) found that power plants using natural gas offer climate benefits over 100 years as compared to pulverized coal power plants even if the methane leakage by the former reaches 5%. In case of availability of carbon capture and sequestration, natural gas offers more benefits over coal, provided that methane leakage rate remains below 2%. During short run (20 years), however, natural gas is as bad as coal if methane leakage is 4%. This finding also resonates with the natural gas GHG footprint figured by Howarth (2014) whereby he concluded that both shale gas and conventional gas have larger GHG footprint than coal or oil. This is because natural gas emits more CH4 than CO2 and the former has more GWP than the latter. Thus, replacement of coal by natural gas can be advised for those countries which have higher natural gas reserves, but methane leakage should be kept at 2% and, where Carbon Capture and Storage (CCS) is available, below 4% in short run and below 5% in the long run.

In those countries where base-load management necessitates usage of coal, most efficient technologies like supercritical technology or ultra-supercritical technology should be encouraged so that more electricity can be generated from less coal. In order to reduce carbon footprint, Integrated Gasification Combined Cycle (IGCC) technology should be encouraged. Recently, China has increased the adoption of IGCC technology. IGCC plants run on 'syngas' fuel from which pollutants have already been removed in order to reduce emission (Holt 2001)

## 6.2. Use of Clean Energy

A significant shift from hydrocarbons to renewable energy (hydro, solar, wind) in recent years has improved the prospects of curtailing the emissions of GHG. Many countries have already set targets for emission reduction; 128 countries out of 197 have ratified the Paris Agreement (UNFCCC 2017). Renewable energy and energy efficiency are key players in reducing emission of GHG. With wind power and Solar Photovoltaic dominating the renewable energy sector, 2015 was the record year to add 120 GW of renewable energy power plants (REN21 2016). Furthermore, per kilowatt prices of wind and other renewable energy resources are failing to near parity with fossil fuels which would be encouraging for their future use. Energy efficiency measures (Green Buildings, LED Lights, Electric Vehicles, etc.) can contribute up to 30% in total emission reduction; recycling economies are contributing up to 10% emission reductions. Pakistan has the potential of generating hydro-energy several times in excess of its present need.

## 6.3. Removal of $CO_2$ from Atmosphere

Newly emerging technologies like CCS can contribute to the goal of offsetting emissions. $CO_2$ removal techniques, which would mitigate the main driver of climate change, include a) Direct air capture: using absorptive substances/membranes to pull out $CO_2$ from air with smokestack-collection system, b) Bio-energy combined with carbon capture and storage. $CO_2$ absorbed by trees; biomass fuels power plants, c) Carbon sequestration whereby accumulated $CO_2$ is compressed and injected deep into the Earth inside stable geologic formations. The $CO_2$ can be used to extract depleted oil and natural gas from reservoirs, d) Enhanced weathering of silicate rocks through slightly acidic rain, and e) Storing $CO_2$: The wastes from industry or power plants as compressed (liquid) $CO_2$ is stored deep within Earth in the rock pores, depleted oil or gas storage sites, or in deep saline formations. Industrial scale carbon capture and storage for coal fired plants must be encouraged and incentivized. Recycling waste material will have direct impact on fossil fuel demand and reduction in the emission of GHG.

Another way to control the carbon emission into the environment is to levy carbon tax on industry. Although Paris Agreement (PA) does not contain direct reference of carbon pricing, paragraph 136 of the COP Decision recognizes the importance of domestic policies and carbon pricing in emission reductions. Marcu (2016) argued that introduction of carbon pricing in the PA would have hampered the negotiations. However, parties to PA can voluntarily introduce carbon tax. An effective carbon tax would be that which is progressive in nature. Mapping of industries can be carried out for identifying red flag industries. Higher taxes may be levied on them.

## 6.4. Increase in Afforestation and Reduction in Deforestation

According to a study published recently, Intended Nationally Determined Contributions (INDC) of countries of Paris Climate Agreement, forests are likely to play a central role in conserving and enhancing carbon sink and decreasing GHG. Assuming that INDC are met by countries in its entirety, forest will serve as a net sink of carbon with capacity of (up to $-1.1 \pm 0.5$ $GtCO_2e$ $yr^{-1}$) by 2030, which is a quarter of the emission reduction proposed by INDC countries. In order to utilize the full potential of forests as mitigation measure, transparent and reliable GHG inventories must be made available by countries. In addition, uniform methodologies of measuring GHG emissions and reduction have to be used by countries in order to enhance the confidence of public and scientists in data (Grassi et al. 2017). As a matter of fact, IPCC has developed a mechanism to report GHG emissions and removal methodologies. However, GHG inventories are required to be transparent, complete, consistent and comparable, which is an inevitable task for developing countries.

Forests and use of land has often been considered as a complex mitigation option. However, after the inclusion of Reducing Emissions from Deforestation, Forest Degradation, and other forest activities (REDD+), countries are now expected to make a full use of land based mitigation measures. One of the most commonly used land based mitigation methodology is termed as Land Use, Land Use Change and Forestry (LULUCF). Brazil, Indonesia, Ethiopia, Gabon, Mexico and Guyana are contributing most to LULUCF mitigation measure. China and India are promoting carbon sink through afforestation. The significance of LULUCF mitigation measure is reflected by the fact that LULUCF contribution is greater than all other sectors of INDC of Brazil. Some research findings suggest that in tropical region, forestation is causing significant cooling effect whereas in other parts of world such as boreal regions extensive forestation may not be entirely helpful in tackling global warming through its cooling effect but rather will add to it (Swaminathan 2007). Additional studies are needed in tropical rain forest areas to see the release of $CO2$ resulting from the rapid forest decay.

Afforestation and reforestation initiatives should be carried out according to scientific need assessments which help in identifying those native and indigenous species that promote biodiversity. The Billion Tree Tsunami Afforestation Project (BTTAP), of Khyber Pakhtunkhwa Province of Pakistan is a case in point. Over 13 indigenous species have been selected for the project, including the endangered species like Taxus Wallichiana (Burmi). Of the total 27 species planted under BTTAP. However, Eucalyptus has been planted the most and its excess may constrict the process of biodiversity (WWF-Pakistan 2016).

## 6.5. Changing our Life Style

Several ordinary measures can result in substantial reduction of greenhouse effects. Apart from above technologies and policies, changing mind-sets of people for energy usage and conservation of water, especially clean water; would be amongst the most effective measures towards climate friendly growth. Some other steps include:

### ***6.5.1.*** *Expanded use of renewable energy in buildings*

Buildings may utilise renewable energy resources like: small solar electric systems (using photovoltaic cells), small wind electric systems, small hydropower systems and small hybrid electric systems (solar and wind). In order to promote their use, fiscal and monetary cushions may be provided to the end consumer.

### ***6.5.2.*** *Reducing waste*

Waste material, especially food scraps, is a source of GHG emissions. Their removal from the landfills has a significant potential for emissions reduction. According to (EPA (2011), removal of food scraps from landfill can help reduce the emissions by 1.5%, 0.8% and 1.8% of overall 2050 emissions reduction goals in California, Oregon and Washington, respectively.

### ***6.5.3.*** *Avoiding unnecessary use of vehicles*

Transportation has 14% contribution towards Global GHG emissions. Less use of vehicles, emplacement of mass transit system and efficient automobile systems can all decrease the level of emissions.

#### *6.5.4. Eating less meat*

As an outcome of enteric fermentation, a natural process, the livestock sector contributes towards methane emission. If meat demand decreases, livestock requirements would also reduce. Nevertheless, if meat consumption decreases, public will substitute it with other food. That food may also result in net emissions during production and processing. Thus, in the end, there may be no substantial benefit. In ruminants methane emission is high because their diet consists of roughages. Addition of Sodium Nitrate and Sulphur in their diet can help reduce the enteric methane production (Arif et al. 2016).

## 6.6. Spatial Planning and Infrastructure

As the world population is expanding so is the urbanisation causing imbalance of ecosystem and increased GHG emission. According to a recent survey, urban cover is bound to expand from 56% to 310 %, which highlights the importance of having sustainable spatial planning (IPCC 2014). Infrastructure design followed by builders has to eliminate "lock in" situation where high level of energy consumption is required, resulting in green house emission. Instead of sprawling cities, vertical cities are found to be more compact and environmental friendly. Need of the hour is to plan and implement smart green cities with little carbon intensive infrastructure.

City or district governments should be leading the process of climate action. They can make such Green Building Codes and Energy Code Standards that end up in efficient use of energy. For instance, New York City established a Technical Working Group (TWG) which produced a report titled 'One City Built to Last: Transforming New York City Buildings for a Low Carbon Future' (MOS 2016). In order to reduce CO2 emissions by 80% till 2050, TWG recommended the following key steps requiring: i) owners of large and mid-sized buildings to repair and improve heating distribution systems, including specific requirements for steam systems, within the next 10 years, ii) owners of mid-sized buildings to upgrade lighting in non-residential areas to meet current Energy Code standards by 2025, iii) owners of large and mid-sized buildings to assess deep energy retrofit strategies as part of the Local Law 87 energy audit through a simple template developed by the City, and iv) Require implementation of efficiency measures in existing buildings by incorporating low- and medium-difficulty measures into the codes or as standalone mandates. The City will begin with requiring digital burner controls for boilers, restrictions on open refrigerators in retail stores, thermal de-stratification fans in heated industrial spaces, sealed roof vents in elevator shafts, and upgrades of exterior lighting to current Energy Code standards.

Another example is that of Canada. It encourages the building of new homes according to the code R-2000. Such homes are very energy efficient since they include: i) High insulation levels in-walls, ceilings and basements, ii) High efficiency windows and door, iii) High efficiency heating, iv) Whole-house mechanical ventilation, v) testing to ensure minimal air leakage, and vi) Water-conserving fixtures.

Just like buildings, more high efficiency appliances have also a high potential of GHG reduction. In an interesting study, Hong and Howarth (2016) found out that a high efficiency electric heating pump is more climate friendly than conventional water storage heater working on natural or shale gas. They predicted great net climatic benefit if conventional heater, fuelled by gas (shale and natural), is replaced by a high efficiency electric pump even if the latter is running on electricity produced by coal power. If the latter's energy source is renewable, the net climatic benefits increase even more. Notwithstanding the benefits of high efficiency appliances, sustainable and rational consumption is also a simultaneous requisite. Efficient appliances consume less electricity and hence entice the consumers to use them for longer hours. Thus they have dual negative effects, i.e., increased use of electricity and higher emissions of CFCs.

### 6.7. Geo-engineering Solar Radiation Management (SRM)

According to some climatologists, it is already too late to achieve the goal set forth in the Paris Agreement (keeping temperature rise within 2°C, preferably 1.5°C by end of the century). Therefore, it may become necessary to adopt a radical approach such as geo-engineering (using techniques that reflect a small percentage of the sun's light and heat back into space) for controlling the heat increase. There are pertinent issues related to geo-engineering such as technological competence to deliberately temper with nature, moral justification, and legal concerns in case of disagreement over its use. It is of utmost importance that solid research is carried out to ensure the safe use of SRM. Developing global consensus over the use of SRM is crucial even when it is considered to be essential. Other aspects which require detailed policy making are the legal and ethical concerns surrounding the implementation of SRM governance (TWAS 2012).

## 7. CONCLUSION

Climate change is one of the most compelling issues of this century. Plethora of evidence and studies suggest that global warming is taking place at an alarming rate. Although climate changes have been taking place in the geological past due to natural causes, the present day global warming is attributed mainly to the release of CO2 in the atmosphere due to anthropogenic activities. Global warming would have a disastrous impact on the socioeconomic development of the world. It will lead to changes in weather patterns, melting of glaciers and polar ice caps, rise in sea level, floods and natural disasters, disease, droughts, wild fires, threat to natural habitat and our ecosystem, insecurity of food and water, poverty, and large scale migration. Steps such as reduction of GHG emission level, removal of CO2 from the environment, use of clean energy and serious drive of afforestation can help reduce the pace of global warming which is the main goal of Paris Agreement. The world can sustain its development provided the climate change and its consequences are dealt with seriously. Therefore, it is necessary for the policy makers to make sound and comprehensive policies, and robust decisions based on optimized prediction of future and are safe to follow, leading to sustainable development irrespective of what the future brings.

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