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INFORMATION AND COMMUNICATION TECHNOLOGIES FOR CLIMATE CHANGE: A WAY FORWARD

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Abstract: *Today's world is full of competition and to fulfil our greed, we are exhausting our natural resource as much as we can. But, consequently we are harming ourselves and are bounded to talk over climate change. Climate is changing from the very beginning of Earth. But, after industrial revolution 1975 this rate of change in climate had increased tremendously due to excess accumulation of Green House Gases. Anthropogenic activities are considered as major factor which is responsible for this change. The major consequence of climate change is Global Warming which is affecting the Ecosystem in many ways. In order to protect ourselves from coming disastrous future we all are trying to find solutions. Information Communication Technologies (ICTs) can be one of tool for these solutions by monitoring, mitigating and helping in adaptation to its ill-effect and assisting in the transition towards a green economy. Climate change is not a problem of India only. The whole world is involved in this so our aim should be to work together for protection of our sweet home called 'EARTH'. This is a review paper, that mainly emphases on climate change, its cause, consequences and role of ICTs.*
Key Words: *Climate Change, ICTs, Green House Gases.*

Introduction: Nature is all about changes, everything in nature keep changing from time to time and place to place. Similarly, climate on earth is also changing naturally from time immemorial. These changes were due to both natural and artificial cause. Artificial cause is also known as anthropogenic activity, which means activity performed by human being. All these activities are to fulfil the never ending greed of human. But, increased momentum of climate change in last few centuries after industrial revolution and its cascading impact is alerting us to take suitable steps to curb this change. ICTs could be an effective tool in monitoring the various disastrous events, mitigating and adapting impacts of climate change.

Climate Change: Earth is the only planet of universe containing life on it. This is mainly due to the atmospheric layer present around the earth, which nourishes and protects life on it. Each layer has its own temperature and composition. Climate on Earth is a multiple cause - effect of interaction between climate system like hydrosphere, cryosphere, atmosphere, lithosphere and biosphere. NASA define climate as the long term pattern of weather in particular area. Any change in these climate system leads to great change in climate [1].

Climate change in Inter Governmental Panel on Climate Change (IPCC) usage 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. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods [2].

Historical Evidences of Climate Change: Climate is dynamic in nature. It changes continuously in very slow motion and it is a

necessary evil. Some evidences of these phenomena are given below:

1. The formation of the Himalayas resulted in blockage of frigid Central Asian air, preventing it from reaching India; this made its climate significantly warmer and more tropical in character than it would otherwise have been [3].
2. Earlier in the current Holocene epoch (4800-6300 years ago), parts of what is now the Thar Desert were wet enough to support perennial lakes; researchers have proposed that this was due to much higher winter precipitation, which coincide with stronger monsoons [4].
3. Similarly, Kashmir which once had a warm subtropical climate, shifted to a substantial colder temperate climate 2.6-3.7 mya; it was then repeatedly subjected to extended cold spells starting 1 million year ago [5].
4. Global sea level rose about 17centimeters (6.7 inches) in the last century. The rate in the last decade, however, is nearly double that of the last century [6].

Causes of Climate Change: Change is law of nature, nothing on earth could remain static and immortal forever. From above examples it is clear that change in climate is a natural phenomenon. This is changing continuously from birth of earth. Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago marking the beginning of the modern climate era—and of human civilization. Most of these climate changes are attributed to very small variations in Earth's orbit that change the amount of solar energy our planet receives (NASA). But current changing trend is very devastating as it is changing at a rate that is unprecedented in the past 1,300 years. A change in Earth's climate mainly occurs due to two primary factors which are:

1. Natural Factors: There are a number of natural factors responsible for climate change. Some of them are:

(a) Continental Drift: Continental drift changed the physical features of the landmass, their position and the position of water bodies. The separation of landmasses changed the flow of ocean current and winds, which affect the climate. Only due to this drift even today, the Himalayan range is rising by about 1mm every year because of the Indian landmass movement, slowly but steadily [7].

(b). Volcanoes: Volcanic eruption throws out large volume of sulphur dioxide, water vapour, dust and ash into the atmosphere. Sulphur dioxide in stratosphere leads to cooling by reflecting the sunlight and screening the ground [8].

(c) The Earth's Tilt: Changes in the tilt of the earth affect the season as more tilt would lead to warmer summer and colder winter; less tilt leads to colder summer and milder winters [9].

(d) Ocean Current: The Ocean is major component of the climate system. It covers about 71% of Earth surface and absorb about twice as much of sun's radiation as the atmosphere or the land surface. Much of heat that escapes from the oceans is in the form of water vapour, the most abundant Green House Gas on Earth [7].

(e) Changes in the Sun's Energy: Climate is influenced by solar energy that reaches Earth. Changes occurring in the sun itself can affect the intensity of the sunlight that reaches Earth's surface. The intensity of the sunlight can cause either warming or cooling (during periods of stronger and weaker solar intensity) [10]. The sun follows a natural 11-year cycle of small ups and downs in intensity, but the effect on Earth's climate is small [11].

2. Anthropogenic Factors: In today's competitive world each and every human on earth wants to gain power, economic strength and social priorities. In order to fulfil our greed, we are not leaving any single stone unturned. We are exploiting our natural resources upto the extent which is beyond the capacity of natural regeneration cycle. Due to this concentration of many toxic chemicals and Green House Gases are increasing in our atmosphere. Green House Gases like carbon dioxide, methane, water vapour, nitrous oxide and ozone have the properties to trap solar radiation within the atmosphere. They absorb and emit radiation within the thermal infrared range and thus causes Green house Effect. Without Green House Gases the temperature of earth would be colder than the present average of 14^0C [12]. Anthropogenic activities responsible for tremendous rise in green house gases are given below.

1. Industries: Industries involved in production of various usable items and are emitting many GHGs. It emitted 19% of 2004 global GHGs emissions from chemical, metallurgical, and mineral transformation processes not associated with energy consumption [13].

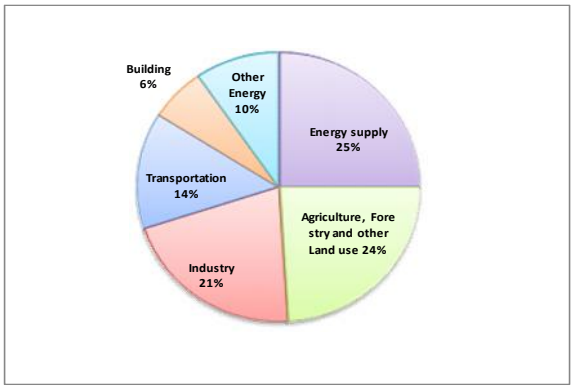
2. Energy Generation: We are burning fuel in order to generate energy in the form of electricity and heat, burning fossil fuel coal, natural gas and oil. This sector generated 26% of global GHGs emission in 2004 [2]. It creates about 23 billion

tonnes of CO_2 emissions per year – in excess of 700 tonnes a second [14].

3. Agriculture: Agriculture is a significant driver of global warming and causes 15% of all emissions, half of which are from livestock [15]. Modern agriculture, food production and distribution are major contributors of greenhouse gases. It contributes by emitting methane gas (CH_4) from marshy area of paddy field and ruminant animal husbandry. Fertilizers and pesticides used in agriculture to increase the yield, also contributes in release of GHGs like NO_2, CH_4, etc.

4. Deforestation: Forest provides us lots of resources of our need. It is a renewable source, but for fulfilling our greed we are exploiting it beyond the cycle of natural rejuvenation. For photosynthetic activity it absorbs CO_2 from the environment and thus reduces its concentration from environment. Thus, deforestation also contributes to global warming. According to IPCC, 2007 it emitted 17% of Global GHGs emission.

Beside these commercial building, transport and waste management contributed in 24% of GHGs emission [2]. According to current data of IPCC 2014 total anthropogenic Greenhouse gas emissions from economic sectors is:



How Greenhouse Effect Causes the Atmosphere to Retain Heat?: When sunlight reaches Earth's surface, it can either be reflected back into space or absorbed by Earth. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). Greenhouse gases (GHGs) like water vapour (H_2O), carbon dioxide (CO_2), and methane (CH_4) absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the "Greenhouse Effect". (http://www.epa.gov/climatechange/science/causes.html)

Consequences of Climate Change: There are many consequences of climate change. Some of the major consequences have been discussed below:

1. Retreat of Glaciers: With few exceptions, all the alpine glaciers of the world are losing mass and it is predicted that this trend will continue as global warming progresses. In areas where the glaciers are melting, river runoff will increase for a period before a sharp decline in runoff [16].

2. Rise in Sea Level: The rise in sea levels is linked to three primary factors, all induced by this ongoing global climate change: (a) Thermal expansion of sea water as the oceans absorbs about 80 percent of global heat. (b) Melting of glaciers and polar ice caps. (c) Ice loss from Greenland and West Antarctica. A recent study says we can expect the oceans to rise between 2.5 and 6.5 feet (0.8 and 2 meters) by 2100, enough to swamp many island nations like Bangladesh, Seychelles, Maldives, etc. and coastal areas of large nations (Ocean.nationalgeography.com/ocean/critical_issues_sea_ level_rise/).

3. Coral Bleaching: When corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues, causing them to turn completely white. Corals can survive a bleaching event, but under more stress they are subjected to mortality. In 1998 coral leaching event killed off more than 70% of coral reef in the reef ecosystem of Lakshadweep and Andaman and Nicobar Island (Oceanservice.nova.gov/facts/coral_bleach.html)

4. Lowering of Ground Water Table: Groundwater resources are related to climate change through the direct interaction with surface water resources, such as lakes and rivers, and indirectly through the recharge process.

5. Affecting Agriculture: Change in climate is affecting agriculture by changing crop cycle, reducing yield, decreasing coastal areas under cultivation, effecting crop's physiology (Warmer temperatures may make many crops grow more quickly, but warmer temperatures could also reduce yields) and ultimately livelihood of farmers.

6. Extreme Temperatures: Due to global warming we are facing hot waves and cold waves in different season. Summer is getting hotter and winter is getting colder in various region of world. This further lead to extreme weather conditions like more hurricane, more

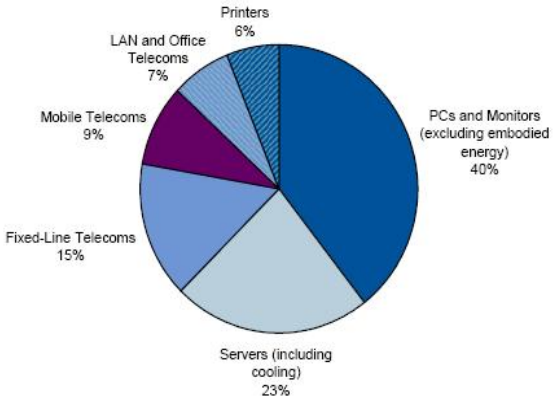
drought, and more cyclone. E.g. sparse and erratic rainfall pattern and a lengthened dry season in Cherrapunji and Mawsynram affecting the livelihood of 1000s of farmer who are cultivating paddy and maize.

7. Increase in Pest and Diseases: Climate change is expected to cause changes in the distributions of species around the world, with an overall shift away from the equator and towards the poles. A report in the journal *Science* in June 2002 described the alarming increase in the outbreaks and epidemics of diseases throughout the land and ocean based wildlife due to climate changes [17].

8. Ocean Acidification: the additional excess CO_2 being absorbed is also resulting in the acidification of the oceans. When CO_2 reacts with water it produces a weak acid called carbonic acid, changing the sea water chemistry. As the Global Biodiversity Outlook report explains, the water is some 30% more acidic than pre-industrial time. The Indira Gandhi Institute of Development Research has reported that climate related factors could cause India's GDP to decline by upto 9%.

Role of ICTs in Climate Change: In past few decades, information and communication technologies have provided us with a vast array of communication channels like social media, instant messaging, video calling, etc. Thus, ICTs is define as an umbrella term that includes any communication device or application, encompassing radio, television, cellular phones, computer and network hardware and software, satellite system and so on, as well as the various services and application associated with them, such as video conferencing and distance learning [18]. It is having both negative and positive effect on climate change.

1. ICTs Causing Global Warming: Information and communication technologies contribute just over 2% global green house gas emission. According to UN report compiled by UN's think tank united Nation University volume of global e- Waste is likely to rise sharply by 21% in next 3 years. However, ICTs can play a significant role in reducing the remaining 98%. According to the World Summit for an Information Society, electricity demand by the ICT sector for industrialised countries is between 5% and 10% of total electricity demand. An important amount of the electricity used by ICTs is consumed when equipment is switched off or is not performing its main function. Mentioned following contribution of various ICTs industries in causing global warming can be viewed through following figure [19].



2. Monitoring Role: It can monitors the changes in climate through remote sensing by acquisition of information about an object or phenomenon without making physical contact with the object, Environmental monitoring (Tsunami early-warning system), Digital climate forecasting models, GPS-enabled telemetry and ubiquitous sensor networks. World Meteorological Organisation is using Global Observing System, Global Telecom System and Global Data Processing system for its world weather watch programme. The World Weather Watch (WWW) Programme facilitates the development, operation and enhancement of worldwide systems for observing and exchanging meteorological and related observations, and for the generation and dissemination of analyses and forecast products, as well as severe weather advisories and warnings, and related operational information.
(http://www.wmo.int/pages/prog/www/wwwinfo.html) Through use of ICTs tools only, we are able to get long, medium and short range weather forecasting, which enable us to plan proper adaptation strategies. Now, we have many institutions and organisations that are involve in climate monitoring work such as, national disaster management council, Net Hope, CDAC network, Digital Humanitarian Network, etc.

3. Mitigating Role: According to Wikipedia Climate change mitigation are actions that limit, stop or reverse the magnitude and/or rate of long-term climate change It mitigate the impact of climate change:

a. Directly, by saving energy through using Next-Generation Networks, Modern radio technologies, etc. Next-Generation Networks (NGN) can reduce GHG emissions by 40% compared with separate fixed and mobile networks and Modern radio technologies can

reduce energy consumption by transmitters ~ 10 times. [19]

b. Indirectly, by carbon abatement through substituting business travel with video-conferencing. Carbon disclosure project India in 2014 has reported that "savings achieved through video-conferencing and telecommuting with moderate ICT penetration in 2030 can offset GHG emissions, more than 70 times the current GHG emissions due to the annual air traffic between Delhi and Mumbai". [20]

c. Systemically, by dematerialisation of natural resources in daily use through Intelligent Transport Systems that reduces vehicle carbon emission below130g per km [19].

4. Adaptation Role: Climate change adaptation is a process by which "strategies to moderate, cope with and take advantage of the consequences of climate events are developed and implemented" [21]. Its role in adaptation can be explored mainly at two levels:

A. National Level: ICTs can contribute to the formulation of NAPAs/national plans in five main domains

- **Informed Decision Making:** Within complex developing contexts, the creation of adaptation plans is an information intensive activity. Knowledge and information inputs from diverse sources like geographic information centre and meteorological information centre can help to inform decision making processes by identifying the specific needs and priorities at the local and national level, as well as the vulnerabilities, resources and capacities available in support of adaptation processes.
- **Stakeholder Engagement:** The formulation of adaptation plans requires a partnership between public, private and civil sectors. ICTs can facilitate the inclusion of multiple voices in the design of adaptation strategies at various levels, from simple broadcast and awareness raising of issues to be decided; to fuller engagement through the use of social media and online polling of those likely to be affected; to the use of group decision support systems to model and analyse different scenarios, and enable decisions to be made.
- **Adaptation Delivery:** Adaptational priorities vary depending on particular national vulnerabilities, and ICTs' role in delivery of those priorities generally relates to specific vulnerability sectors or issues.
- **Feedback and Learning:** The generation of feedback, the creation of new knowledge and the dissemination of existing and emerging experiences are key components of successful adaptation strategies. ICTs can help bridge the missing link by providing feedback on the impact of adaptive actions through geographical and sectoral information systems.
- **Institutional Capacity–Building:** The four areas for ICT application described thus far strengthen the institutions involved in adaptation strategies, and can foster a broader capacity building process aimed at providing a digital institutional infrastructure that can readily develop, share and utilise a whole range of digital data.

B. Sectoral Level: The role of ICTs in delivery of adaptation actions can also be analysed from a sectoral perspective, by linking their potential to the specific needs and priorities of key sectors affected by climate change, as specifically detailed in following table:

Vulnerable Sectors	Examples of Adaptation Measures	Sample Areas of ICT Potential
Poverty	• Increasing income	• ICTs can be used to get money; most obviously through enabled or menabled remittance systems. • ICTs can be used to better manage money; for example through m-finance and m-banking applications, and also (overlapping with the category above) through ICT enabled microfinance. • ICTs can be used to make money through the formation of ICT enabled microenterprise, including ICT based retailing (e.g. sales of mobiles, accessories and calls), creation of digital content (e.g. music, photographs), digital services (e.g. cyberkiosks, telecentres), and digital production (e.g. data entry, digitisation)
Water Resources	• Better management and use of water supply • Development of flood controls and drought monitoring • Water policy reform	• ICT applications such as GIS and remote monitoring can support the improvement of water resource management techniques, and the monitoring of water resources. Software and ICT based models can contribute to water security by helping to manage and document scarce water resources (e.g. melting glaciers, salinisation and pollution of fresh water sources), and water distribution. • ICTs such as mobile phones can be used in participatory monitoring systems, enabling users to provide near-real time data during the

		occurrence of floods or droughts. • ICT tools can also help to monitor water supply levels and the degradation of water quality due to increased temperatures and pollutants, providing updated data that can inform policy processes including those related to pricing and irrigation.
Agriculture & Food Security	• Development of tolerant/resistant crops • Diversifications of crops • Supply chain strengthening • Policy measures	• ICTs can be used to access information and knowledge to strengthen local agriculture and livestock production systems. Applications such as mobile phones and community radios can be used to disseminate information in appropriate, simple formats on new seeds and crops variety, livestock breeds, irrigation applications, reminders about planting dates, pest and disease control, livestock vaccinations, alternative fertilizers, among others. • The use of ICTs such as mobile phones can also help to improve market access (through information on prices and consumer trends) and support capacity building opportunities for local farmers via better links to suppliers. • GIS and related applications provide essential data for monitoring short and long terms agricultural trends that inform policy formulation and implementation.
Human Health & Habitat	a) New or improved disease/vector surveillance and monitoring. b) Changes in urban settlements and housing design	• ICTs such as community radio can help to raise public awareness on methods to prevent or mitigate the spread of some vector borne (i.e. malaria and dengue) and water borne diseases. Web and mobile applications can draw data from, and provide guidance to, healthcare professionals. • ICT applications can be used in urban planning (i.e. GIS), and in monitoring and provision of relevant environmental information to support • Decision making processes contributing to the adaptation of human habitats and infrastructure. • ICTs are central to monitoring the displacement and settlement of populations due to sea level rise, drought, desertification, etc.
Terrestrial Ecosystems	• Creation of parks/reserves and protected areas • Better assessment of the vulnerability of ecosystems • Monitoring of species/biodiversity	• GIS and remote sensing applications can provide valuable information to manage and monitor parks/reserves and protected areas, contributing to the conservation of ecosystems. • ICT applications are used in climate models and predictions to inform Decision making processes and raise awareness on the impacts of climate change in local and national biodiversity. ICTs can provide illustrations, satellite images and photographs related to human and climate change impacts on the environment.
Coastal Zones & Marine Ecosystems	c) Better coastal planning and zoning d) Development of legislation for coastal protection e) Research and monitoring of coastal ecosystems	• ICTs can be used for mapping, visualisation and generation of real time data to monitor short and long term trends affecting coastal ecosystems. GIS and remote sensing applications can support coastal planning and zoning, by providing updated and locally relevant information for decision makers. • Mobile technologies (e.g. smart phones and PDAs) are used to facilitate the collection, retrieval and analysis of data, as well as its dissemination of information in near real time in order to mobilise diverse stakeholders towards local conservation actions.
Disaster Management	• Early warning • Disaster response • Reconstruction	• ICTs such as mobile phones and local radio are central to broadcast of disaster early warnings. • ICTs enable rapid data gathering during emergency response, prioritised decision making, and facilitate logistics. • Decision support and geoinformatic systems underpin the planning of post disaster reconstruction; ICTs can also help to mobilise and monitor reconstruction efforts.

Source: ICTs' Contribution to Sectoral Adaptation Measures & areas of ICT potential [22]

A few examples of identified ICT solutions in different sectors are [20]:

1. Building Sector

(a) Remote Management Systems: Remote management systems when integrated with the smart grids allow consumers and utility companies to more closely monitor power grid activity and appliance power usage. These systems can allow buildings to communicate with utilities, and lead to faster demand response and increased energy efficiency. For example, remote Management systems can empower the grid to reduce specific load at the time of peak shortage by load shedding at selected points.

(b) Building Management Systems (BMS): During the operation phase of buildings, ICT solutions like BMS can be used to automatically control and adjust heating, cooling, lighting and energy use, and regulate the buildings' behaviour and performance to changes in the external environment and needs of the users. These systems are the most promising technology for enabling energy savings in the sector by optimizing operation and output of equipment and reducing excess energy consumption.

2. Transport Sector

(a) Intelligent Traffic Management Systems (ITMS): ITMS encompasses a wide range of ICT enabled tools for managing transport networks. These tools also referred to as "transport telemetrics," and are based on three core principles- Information, Analysis and Dissemination. These tools are capable of offering real-time information about current traffic conditions for a network and on-line information for journey planning. Fuel economy is linked both to average speeds and to the relative proportion of acceleration to steady state driving over a given distance. ITMS can contribute to reducing congestion and ultimately reducing the fuel intensity of transport in the country.

(b) Supply Chain and Logistics Optimization: In transport, supply chain and logistics optimization is an area where ICT can play a significant emissions abatement enabling role. There are various innovative ICT solutions for supply chain management from materials sourcing and selection to delivery of the final product to consumers and end-of-life product management. These can not only improve the business' carbon footprint but also increase efficiency within the supply chain.

3. Industry Sector

(a) Smart Grids: Smart grids are electrical grids that are capable of responding to changes in conditions in the demand and supply of power in an electricity system and are designed to route power in the most optimal way. A smart grid applies sensing, measurement and control devices to capture information from power generation, transmission and distribution and consumption components of the grid.

(b) Advanced Process Control (APC): APC improves industrial process profitability by enhancing quality, increasing throughput, and reducing energy usage. Key Features of an APC are:

- Process Modelling: Quantifies cause and effect relationships, accurately representing process behaviour, to provide better understanding of problems and assists in controlling them.
- Controller Generation: Allows the system to automatically generate a robust and accurate multi-variable controller
- Real Time Adaptive Control: Enables the control system to be adapted to prevailing process conditions on-line
- Constrained Optimization: Permits operation within the physical constraints of the process, allowing for optimization of the process for a given set of conditions.

ICTs have greater potential to reduce the GHGs as it can connect whole world.

Conclusion: In last few centuries climate is changing at a much greater momentum. This all is due to demand for excess energy to fulfil our greed and to achieve higher success in this competitive era. For this, we are exploiting natural resources up to its maximum possible level and ultimately play a vital and most prominent role in increasing GHGs. Due to this change in concentration. We all are facing many problems like irregularities in weather, natural hazards, etc. This entire problem can be minimised up to a greater extent by using ICT Techniques. As ICTs help us in monitoring the event, mitigation and adaption to these events of climate change by using minimum energy.

Since, all countries are connected to each other through aerial medium and air doesn't belong to any individual country. It is a problem of whole world. So, our aim should be to work together for protection of our sweet home called 'EARTH'. Seven billion Dreams: One Planet, Consume with care is the theme for 2015 world environment day.

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