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INFORMATION AND COMMUNICATIONS TECHNOLOGY FOR ENVIRONMENTAL SUSTAINABILITY.

Thesis

CENTRIA UNIVERSITY OF APPLIED SCIENCES

Degree Program in Information Technology

January 2016

ABSTRACT

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Degree programme Information Technology		
Name of thesis INFORMATION AND COMMUNICATIONS TECHNOLOGY FOR ENVIRONMENTAL SUSTAINABILITY.		
Instructor Vidjeskog Johnny		Pages 30+5
Supervisor Vidjeskog Johnny		
<p>The purpose of this thesis was to look at the potential role that Information and Communications Technology (ICT) plays at different stages of the process of climate change, from contributing to global warming, monitoring, and mitigating its impact on the most vulnerable parts of the globe (Africa). While Developing long-term solutions directly in the ICT sector and in other sectors like energy, transport, building, and in the mining sector.</p> <p>Furthermore, this thesis also looked at the impact of ICT goods, networks and services, agreement to focus on energy and Green House Gases (GHG) emission, where CO₂ emission is expected to be cut down by 20%. And also, in organizations and projects, focusing on the ongoing UN summit on climate change in Paris, France, where the budgeting on climate change was adopted. The final sections examine what the International Telecommunication Union (ITU), Telecommunication Standard sector (ITU-T) and United Nations (UN) are already doing in this field and describe strategic options for the future.</p>		

<p>Key words Climate change, environment, information, technology, sustainability</p>
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CONCEPT DEFINITIONS

BCG	Boston Consulting Group
BEMS	Building Energy Management systems
CO ₂	Carbon Dioxide
CEA	Consumer Electronic Association
DSL	Digital Subscriber Line
FTTH	Fiber to the Home
GDP	Gross Domestic Product
GHG	Green House Gases
GPS	Global Positioning System
GOS	Global Observatory System
GSM	Global system for mobile communication
NGN	Next Generation Network
IPCC	Intergovernmental Panel on Climate Change
IP	Internet Protocol
NASA	National Aeronautics and Space Administration
MDG	Millennium Development Goal
MDG7	Millennium Development Goal number 7
ICT	Information and Communication Technology
IT	Information Technology
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
OSI	Open System Interconnect
PCs	Personal Computers
PSTN	Public Switch Telephone Network
RFID	Radio-Frequency Identification
TCP	Transmission Control Protocol
UN	United Nation
UN	United Nation
WWF	World Wildlife Fund for Nature

ABSTRACT

CONCEPT DEFINITIONS

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1 INTRODUCTION

The impact of human activities on the environment and on climate change in particular are issues of growing concern confronting life on Earth and also Information and Communications Technology (ICT). Information Technology is one of the widest field of studies that exist, it ranges from creating software, robotics, chemicals, and destructive substance to normal sharing of information. Although ICT requires energy resources, they also offer a series of opportunities to advance global environment research, planning and action. This may include monitoring and protecting the environment, mitigation and adaptation to climate change. Nowadays the world leaders are busy using the science of technology and its innovations such as biogenetic to destroy humans and our planet earth. In addition human activities such are deforestation, industrial revolution, and mining are some of the great inventions arising from the technology. The primary principle of technology was to help and assist humans in their day to day life, eased of work and studies, evolving from energy usage and high man power to efficient and low energy usage methods to solve problems in the fastest way possible.

Throwbacks of some of the great works and inventions that have led to the ease of humanity. Referring to some scientist such as Albert Einstein, Sir Isaac Newton, Aristotle and Galileo Galilei who are the greatest contributors of modern technology and development. Albert Einstein created the theory of relativity. He also contributed significantly to quantum mechanics and cosmology development. Aristotle, was a philosopher who invented logic, metaphysics and politics. Sir Isaac Newton created the Newton's laws in physics, laws of motions, universal gravitation which dominated scientists' view of the physical universe for three centuries. In addition to that, he also contributed in Kepler's laws of planetary motion from his mathematical description of gravity. Galileo Galilei was a physicist, engineer, philosopher and mathematician who played a major role in the scientific revolution during the Renaissance. He was also known as the father of observational astronomy.

Today, the situation has changed, some of the creations of scientist such as William Moore who created the rocket equation, are more concerned with innovations and creations that could destroy the world and the people living in it. One of this innovations is industrial revolution, the change from manmade and hand made things to machines and manufacturing, which has led to harmful and disastrous waste from the residues of the products. The invention of guns and bombs are also the works of scientist but they are being used today to destroy humanity and

the environment. Human activities on the planet Earth have brought a huge problem which does not only require an individual, be it an engineer, a philosopher, a historian or a farmer, but everyone has the duty to respond to the effect of human activities, which is changing the climate.

When talking about climate change, it may refer to a change on average on the atmospheric conditions, in the time variation of weather about long-term average conditions. Climate change is caused by factors such as living things that shape the processes of ecosystem, variations in radiant energy emitted by the Sun, which is received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warming, which are deforestation, mining, factories and companies waste products. Human activities are known to be the major contributor to the changing climate, for which carbon dioxide (CO₂) is the main cost it.

The aim of this research is to answer some fundamental questions on how ICT can assist in mitigating climate change. Talking about climate change and global warming, it refers to the effect of changing climate that is causing the increase in temperature of the Earth, thereby leading to global warming. Taking Africa as a case study, Africa is the most vulnerable to the changing climate although this continent contributes little or nothing to the increasing temperature of the climate. Information Technology is one of the most significant technology in which the researcher believes can help eradicate and mitigate climate change, or contributes to the factors of mitigation.

This thesis work presents the results of research that illustrates that ICT can assist significantly in the reduction of Greenhouse Gas (GHG) emission while increasing energy efficiency and reducing the use of natural resources. It also reviews the key ICT trends and provides an overview of the impact that ICT are having on the environment and climate change as well as their role in assisting humans to mitigate and adapt to these changes. Intended as a solution or way forward to developing countries such as Asia and Africa, this thesis approaches the topic from a developmental perspective and is based on extensive online research. Upon completion of these thesis, the researcher will answer questions such as:

What is climate change?

What are the causes of climate change?

What is the best technology for fighting climate change?

Establish how ICT is contributing to climate change,

Determine the role of ICT in mitigating climate change,

Can IT be a key technology to help mitigate climate change?

If yes, what can it do? And if No, how can it contribute to the Mitigation process?

2 REVIEWING CLIMATE CHANGE

Throughout history, the Earth's climate has been changing. This has been proven through results from earth's orbiting satellites, and technological advancements, after some 50 years of data processing on different types of information about the planet on a global scale. In the mid-19th century, the heat trapping nature of CO₂ and other gases has increased. More to that, other evidence of rapid climate change includes rising sea level, warming ocean, shrinking ice sheets, declining arctic sea ice, extreme events such as wind, glacial retreat, decrease in snow coverage, and ocean acidification. These and many more, prompted the researcher to review the midpoint between ICT and climate change. Some works such as the role of information and communication technologies for community based adaptation to climate change, had earlier been done on ICT and climate change, even though most of it focused on strategies that are not focused on developing nations, meanwhile the poor developing nations are the most to be affected by climate change. (IPCC 1996, 39-46.)

On global issues on climate change, the global surface temperatures have warmed by up to 0.8 degrees Celsius and statistics have shown that sea level has risen by 10 – 25cm in the last 100 years (NASA 2015). These and other evidence are sufficient of being convinced that climate is changing and will keep changing if no measures are taken against it. Recently, from November 30 to December 11, 2015, the world's leaders under the umbrella of the United Nations (UN) held a UN conference on climate change, which aimed at limiting the CO₂ emission and also reducing the atmospheric temperature by 2 degree (UN 2013).

2.1 Definition of climate change

IPCC (2007) defines climate change as any change in climate over time, whether due to natural variation or as a result of human activities. This definition revealed the fact that there are two major contributors to climate change. However research has shown that human activities are the major contributor to climate change. It is vital to note that the single human activity that has a large impact on the climate is the burning of fossil fuels, such as coal, oil and gas. Other human activities whose contributions are modest include deforestation, fertilizers and other chemicals. But focus on this thesis work is how ICT is contributing to climate change. (IPCC 2007.)

2.2 Signs of climate change

On a general platform, previous studies (IPCC, 2007) have shown that climate change can have serious developmental effects that hit particularly hard on those countries that are already experiencing the hardships of poverty and marginalization. There are clear evidence which shows that climate change is occurring such as Earth orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting several types of information about the planet and its climate on a global scale. These pieces of information, collected over many years, revealed the signals of a changing climate. Experiments carried out by the National Aeronautics and Space Administration (NASA), shows that the heat trapping nature of carbon dioxide and order gases, demonstrated in the mid-19th century, shows that their ability to affect the transfer of infrared energy through the atmosphere is getting difficult, thereby increasing the levels of greenhouse gases that are causing the Earth to warm. (NRC 2006.)

Order signs include a rise in sea level which indicate that sea level have been rising about 17 cm in the last century and it is doubling as of the statistics conducted recently. Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment shows that Greenland lost about 150 to 250 centimeters cube of ice per year between 2002 and 2006, while Antarctica lost 152 centimeters cube of ice between 2002 and 2005, (NASA, 2005). Glacial retreat is also one of the vital signs of climate change. Glaciers are retreating almost everywhere around the world, including Alps, Rockies, Alaska, Himalayas and Africa. Nowadays, events such as hurricanes, floods, heat waves, and rainfall, have been in their extreme occurrences. In addition, since the beginning of the industrial revolution, the acidity of surface ocean water has increased by about 30 percent and it is basically due to human activities. (NASA 2015.)

3 ICT CONTRIBUTION TO CLIMATE CHANGE

Having undertaken a chronological review of the emerging data in the field of ICT, climate change and development, the researcher can now move to develop an overall model to describe how ICT is contributing to climate change and global warming. Recent activities in ICT use globally have impacted the environment negatively (in terms of waste and energy consumption) but also have the potential to support biophysical activities, such as the targets set within the Millennium Development Goal (MDG) number 7 (MDG7) to “ensure environmental sustainability”. The ICT industry and its activities contribute to about two percent of the world’s global temperature rise. Components and devices used in the field of IT are so small but are contributing less in global warming but can be improved to mitigate the rate of heat emission to the atmosphere. Some key points in IT industry and its related compartments are discussed in the following subchapters. (MDG 2013.)

3.1 Infrastructural Development

Buildings, company structures and industries are built with the least possible technology around the world. Recently, urbanization in emerging economies are increasing the population of the world by almost three billion over the next 25 years. In this regard, there are significant demand of urban planning because as of now in the developing countries there are no maximization of energy efficiency in buildings. Meanwhile within the EU buildings are responsible for 40% of greenhouse gas emissions. In Africa, there are very few energy efficient houses, though very little is done with companies and industries. Two key areas of focus to generate greater energy efficiency in buildings are discussed in the following subchapters. (Capon & Oakley 2012.)

3.1.1 Building Energy Management systems (BEMS) in Existing Buildings

In infrastructural Development, greater smart management of energy use through BEMS in which will schedule the operations of major equipment including chillers, boilers, air conditioners, heat pumps, lights according to need, reducing unnecessary use and minimizing wear and tear on equipment. In BEMS, features such as demand limiting, load shifting, advanced time of day, on peak/off peak or other billing rates, also industrial products used in home wiring and

connections also improved to increase efficiency and provide low resistance to data flow. In data, transmission infrastructure on existing buildings would also be affected by climate change due to their resistance, quality of Material used for their production relating to the time period of the climatic state during production. (Lefort 2014.)

3.1.2 New buildings

In new buildings, build-in energy supply and improved on ICT- enabled energy efficient design are used in buildings, including greater use of efficiency principles in position and shape of the building as well as designing windows, lighting, shading and insulation. New buildings can also be linked and delivers integrated solutions where energy production and use are optimized. In new buildings, incorporating and adopting BEMS, the total CO₂ produced by building will be reduced and it will turn buildings from large energy consumers to net producers with approximately 50% of CO₂ emission coming from buildings will be reduced and it will be the biggest opportunity towards a low carbon economy. Climate change will impact ICT by overheating data centers, exchanges and base stations, reducing the strength and quality of wireless signals and increasing operation and maintenance costs. (Cam 2012.)

3.2 Transportation

Climate change may be one of the most significant issues facing transportation today. Scientific consensus on climate change has grown so fast in recent years as advances in analysis have been achieved. Transportation professionals and scientists are very much aware of the effects of weather on transport system performance, and transport infrastructure, which was designed for typical weather patterns, reflecting local climate and incorporating assumptions about a reasonable range of temperatures and precipitation levels. On a global scale, climate change will affect transportation primarily through increase in several types of weather and climate extremes, ranging from very hot days, intensive hurricanes, high precipitation events, drought, and rising sea levels, including storm surges and land subsidence. (Potter 2002.)

The impacts of climate change on transportation will vary by mode of transportation and region of the country, but they will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems. Above all, the infrastructure will be affected most by those

climate changes that cause environmental conditions to extend outside the range for which the system was designed. The greatest impact of climate change for America and Europe will be flooding of coastal roads, railways, transit systems and runways because of global rising sea levels, coupled with storm surges and exacerbated in some locations by land subsidence. (Transportation Research Board Executive Committee 2008.)

TABLE 1: Potential Climate Change and Illustrations on Its Impacts on Transportation

(Transportation Research Board Executive Committee 2008.)

Potential Climate Change	Impacts on Operations	Impact on Infrastructure
Increase in very hot days and heat waves	<p>Impact on lift-off load limits at high-altitude or hot weather airports with insufficient runway lengths, resulting in flight cancellations and/or weight restrictions.</p> <p>Limiting construction activities due to health and safety concerns.</p>	<p>Thermal expansion on bridge expansion joints and paved surfaces.</p> <p>Concerns regarding pavement integrity, traffic-related rutting, Rail-track deformities.</p>
Increase in Arctic temperatures	<p>Longer ocean transport season and more ice-free ports in northern regions.</p> <p>Possible availability of a northwest passage.</p>	Shorter season for ice roads.
Rising sea levels, combined with storm surges	<p>More frequent interruptions to coastal and low-lying roadway travel and rail service due to storm surges, requiring evacuation and/or changes in developmental patterns.</p> <p>Potential closure or restrictions at several of the top 50 airports that lie in coastal zones, affecting service to the highest density populations in the US and Europe.</p>	<p>Inundation of roads, rail lines and airport runways in coastal areas</p> <p>More frequent or severe flooding of underground tunnels and low-lying infrastructure, erosion of road base and bridges</p>
Increase in intense precipitation events	Increase in weather related delays and traffic disruptions.	Increase in flooding of roadways, rail lines, subterranean tunnels and runways.

	<p>Increase in airline delays due to convective weather.</p> <p>Increased flooding of evacuation routes.</p>	<p>Increase in road washout, damages to rail-bed support structures and landslides and mudslides that damage roadways and tracks, also damage of pipelines.</p>
<p>More frequent strong hurricanes</p>	<p>More frequent interruptions in air services,</p> <p>potentially more extensive emergency evacuations,</p> <p>More debris on roads and rail lines, interrupting travel and shipping.</p>	<p>Greater probability of infrastructure failures,</p> <p>Increased threat to stability of bridge decks,</p> <p>Impacts on harbor infrastructure from wave damage and storm surges.</p>

As a whole, all modes of transportation are vulnerable to climate change, ranging from infrastructure to equipment used for transportation. They will vary depending on their location, mode and conditions. According to recent scientific assessment (IPCC 2007), the IPCC Fourth Assessment Report, the greatest impact of climate change on Africa and North America's transportation system will be coastal flooding, especially along the Gulf and Atlantic Coasts, because of sea level rise. All these processes are cost by combustions from cars, plans and many more. (ACIA 2004.)

3.3 Infrastructural risk analysis in Africa

Africa is the continent which is suffering the highest effects of climate change. Given its geographical position, the continent will be particularly vulnerable due to the considerable limited adaptive capacity coupled with widespread poverty and the existing low levels of development. In Africa and other developing countries in the world, climate change is a threat to economic growth, long-term prosperity, as well as survival of already vulnerable populations. African's human existence and development is set to be under threat from the adverse impact of climate change. Its population, ecosystem and unique biodiversity will all be the major victims of global warming. (IPCC 2007).

A summary of the projected impacts of climate change in Africa shows that by 2020, between 75 and 250 million people in Africa are projected to be exposed to increased water stress due

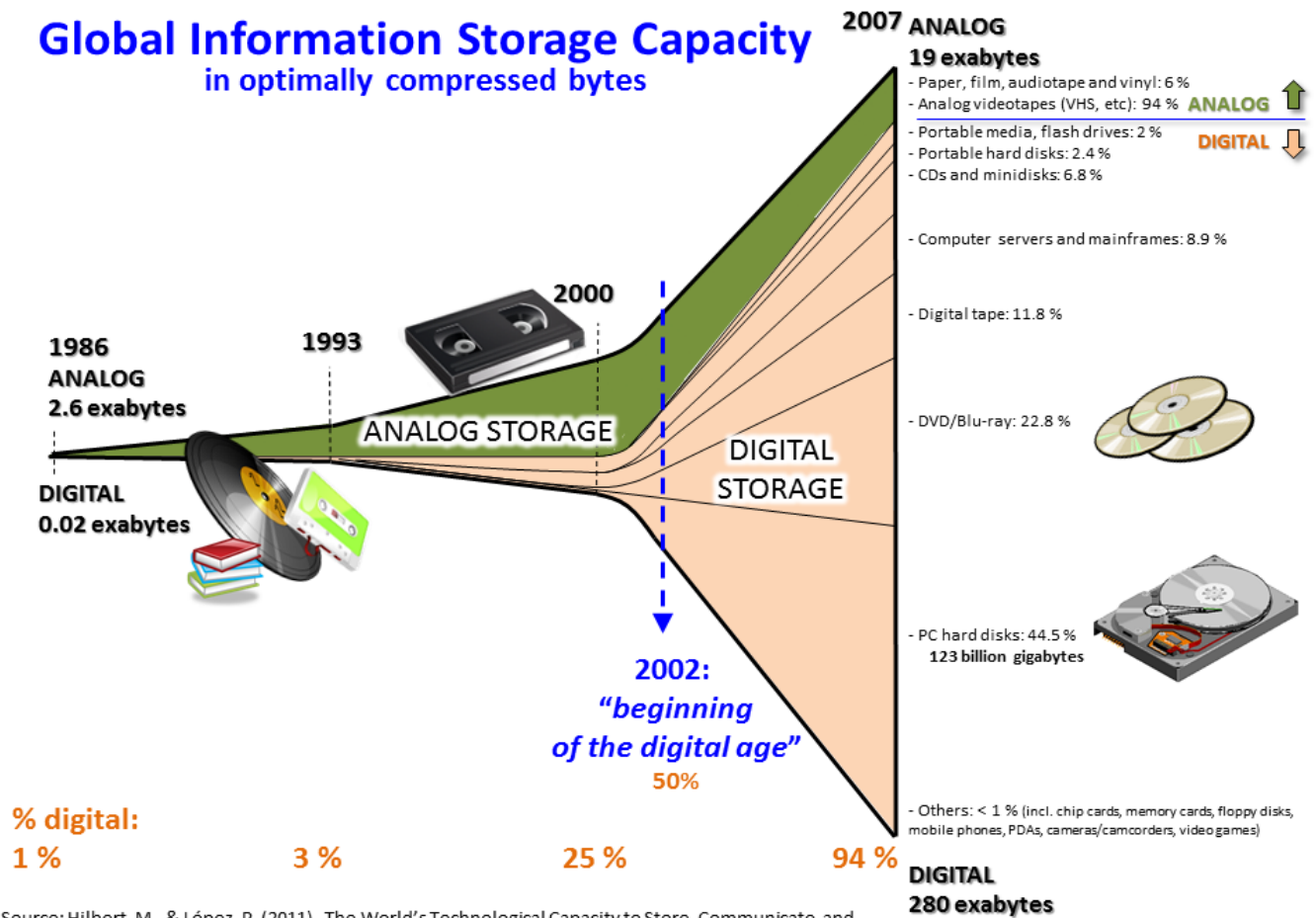
to climate change which will cause flooding and lack on portable water for human consumption. Also, by 2020, in some countries like Ethiopia, Cameroon, Nigeria, and Tanzania, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries are projected to be severely compromised, which will adversely affect food security and exacerbate malnutrition. Towards the end of the 21st century, projected sea level rise will affect low-lying coastal areas with large populations. Finally, the cost of adaptation could amount to at least 5 to 10% of Gross Domestic Product (GDP). (IPCC 2007).

4 HOW TECHNOLOGY IS FIGHTING CLIMATE CHANGE

In the early 2014 research by UNDP on how information technology can fight climate change in the domain of information and communication technology were mentioned but no real solution could be accomplished because of its complexity and its contribution to global warming. From automobiles to factories, technology has been playing its part in climate change. But technology can also change the course if it can be harnessed in effective ways to minimize its contributions to global warming. Some of the ways technology can fight climate change are discussed in the following subchapter. (Wilson 2014.)

4.1 Big Data

Big Data is a term for data sets so large or complex that traditional data processing applications are inadequate. From the age of industrial revolution, data processing and storage have been evolving from analog to digital storage mediums. From figure 1, global Information storage capacity, Information revolution is currently moving from analog to digital stage which is one of the ways by which technology is fighting climate change. From the beginning of 2002, the digital age was born from which data storage has been evolving thereby reducing the method of production from traditional means of data storage. Information storage is one of the highest problems in the digital world of today, these caused companies, industries, and institutions to turn to the traditional methods of information storage which on a primary stage of production of these devices are the fundamentals of climate change. Big Data will assist in combating global warming in that the transformation and storage medium of information in the cloud will be accessed from anywhere any time. (UN 2015.)



Source: Hilbert, M., & López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, 332(6025), 60–65. <http://www.martinhilbert.net/WorldInfoCapacity.html>

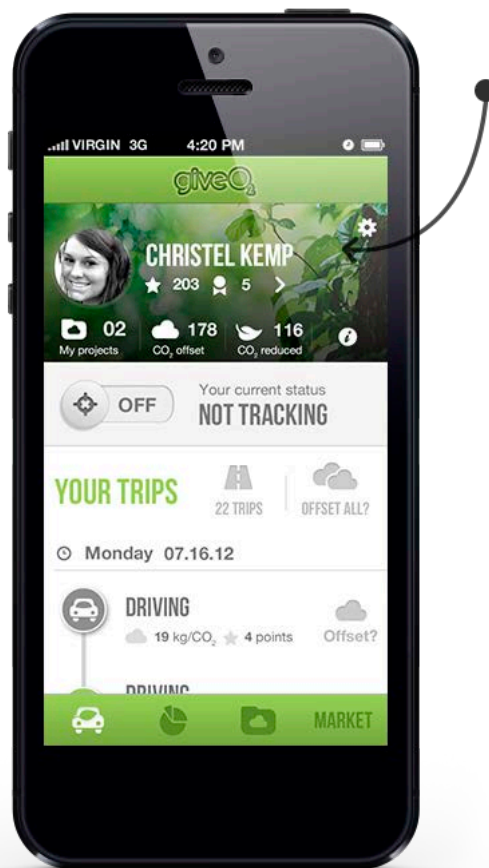
GRAPH 1: Global Information Storage Capacity (Hilbert, M. 2011.)

4.2 Mobile Apps

Mobile gadgets are one of the best methods to create awareness on the existence of climate change and its methods to eradicate or minimize its causes. Ignorance is the most reasons why our climate is changing, therefore mobile applications could help study the rate of human contribution, which is known to be the highest contribution to climate change. It will go a long way to reduce the impact of global warming. Developing applications for flood forecast, for which users will register their address and will receive push alerts notifying them when that address is in danger of flooding, modeling community erosion from climate change, this application when installed users will be able to detect current and future soil erosion with high-

resolution scientific data, it will also allow users to locate sites with high vulnerability to erosion. (OROECO 2016.)

In addition to the above mentioned, Applications such as OROECO, which is an App that tracks your carbon foot print by placing a carbo value on everything you buy , eat and do, then shows you how to compare with orders to able to win prizes, Paper Karma is another easy to use application to cut paper waste. It takes control of your paper mail and help save the Earth. And finally, Give O₂ is another application that tracks your carbon foot print as you travel as shown on the picture below. (Lyndsey 2014.)



GRAPH 2. Give O₂ Mobile APP for Carbon footprint (Kemp 2012.)

All these and many more are applications that will help us know the amount of emissions we are contributing to global warming and how we can limit it and win prizes from the UN mission on climate change. It is also imperative for everyone to take it as a responsibility to monitor the amount of waste disposal to the environment. (Kemp 2012.)

4.3 The Internet of Things

This is an application that helps to turn off or turn on the lighting system and appliances in the house. Monitoring our energy usage makes it possible to be smarter about it, like for an example, NEST which is a devices that controls the rate of heating or cooling, it serves up to 20% of energy that could be wasted with an un-programmed thermostat. With NEST, you can control and monitor your home from a distance, which make it a good application to save a great deal of energy on daily basses. Apps such as IFTTT which connects your favorite applications together for you to have ease of usage and save time and energy. It also hooks up many different types of systems. The Internet of Things (IoT) can also incorporate things such as monitoring your sprinkler system to save water or use sensors to tell you the fasted route to your destination, thereby reducing the carbon foot print. (IPCC 2007.)

4.4 Meat Replacement

Results from Food and Agricultural Organization (FAO) and World Wildlife Fund for Nature (WWF) shows that livestock industry is one of the greatest contributors to climate change. It takes more power to make one burger than to fully power seven iPad, beef alone requires 25 times more production space than pork or chicken, about 10 times more water and 5 times more climate-warming emissions, which is estimated to be the firth of total emissions, according to a newspaper published by Bard college, the Weizmann Institute of Science and Yale University. Calculations of the various items used in beef production between 2000 and 2010 from the U.S. Department of Agriculture, Interior and Energy about land area, water and nitrogen fertilizer to determine the growth of animals, shows that beef requires 30 times more land , 10 times more fertilizer and water. Technology and the IT industry is working and making it easier to cut out the animal-based foods. A plant protein called Beyond Meat is a plant protein that looks and tastes like meat. Modern Meadow uses tissue engineering to make leather and meat products. (Rachel, 2015.)

4.5 Data Centers

Studies and research shows that data centers are a major contributors to global warming in the IT industry sector, also they consume the highest energy from the non-renewable energy sources like fossil fuels, and petroleum products. Industries such as Apple, Google, and Facebook which are one of the largest companies with server farms are drifting towards using renewable energy sources such as solar panels, wind stations to power their server stations. Apple now boasts that it uses 100% renewable energy in their data centers especially aided by the largest private solar array in the United States. Google is moving toward that goal as well, though they use 34% right now. It is imperative to note that the energy usage in the data centers, are not directly related to technology, but to cool the servers from overheating. In a bit to reduce over heating in data centers, efficiency of the servers is being enhanced. (Joe 2013.)

Further research carried out by the researcher from a correspondent in Green House Data shows that Amazon and Microsoft's are information technology companies that focuses on energy output efficiency as shown on the block below. From Data center energy use, world wide Data center use is surging with streaming video, mobile data usage, and business infrastructure all using the cloud. That is a whole lot of energy pulsing through data centers across the globe, making energy efficiency a top priority for service providers. (Joe 2013.)

4.6 Geoengineering

Geoengineering, sometime referred to as planet hacking, is a controversial method to which scientist believe they can use to revert climate change for which the IT industry is taking in to it seriously to build soft wares, applications for which geoengineering can function properly, efficiently and distributive to every with the urban and the rural areas of a country, continent or the world at large. Geoengineering takes in to consideration, carbon dioxide reduction and/or solar radiation management. (Graham 2014.)

In carbon dioxide reduction, geoengineering takes in to consideration circumstances like building algae farms, planting trees, which is the most primary concern of Africa and Asia, capturing emissions from power stations for fuel. Meanwhile, for solar radiation management, geoengineering takes in to consideration situations such as releasing volcanic ash as a coolant, arranging mirrors in space to redirect solar rays, painting roofs white instead of black. All these

and many more, are some of the ways and developments industries and the population at large are doing to fight climate change or revert its effects. (Graham & lyster 2014.)

5 ENVIRONMENTAL EFFECT OF INFORMATION TECHNOLOGY

Information technology as a whole, is one of the most advancing industry in the world, developing its strategies to improve on the quality of products it is having, the quality of service it renders and limiting its effect on the environment and the population at large. The most important environmental effects of information technology can be summarized in the following four sub headings as follows. (Kozlowicz 2015.)

5.1 The manufacturing of IT equipment

According to ITU-T, there are 10 billion Personal Computers (PCs) worldwide and is expected to increase to about 20 billion by 2020. With this we expect that the ratio of IT contribution towards GHG emission is expected to increase at an alarming rate. PCs and monitors contribute to about 40% of total ICT carbon emissions which is equivalent to about 50 million cars on the road. According to sustainable Information Technology, 2005, UN studies shows that a single computer screen manufacturing consumes 530pounds of fossil fuels, about 50 pounds of chemicals and 3000 pounds of water, the total material consumed in manufacturing is more than the average weight of an average car. One of the most toxic material in the IT industry is Lead (Pb), about 0.4 to 1kg of lead is found in each computer display. Lead has several environmental effects, for example it can damage the blood and nervous system of humans. (ITU-T 2005.)

Furthermore, according to the researcher, the manufacturing of ICT equipment such a cables, end user devices such as telephone, smart phones, tablets, computers, laptops, diodes, servers, and many more also produce harmful effects to the environment and therefore should be redesigned to use materials with low or no negative effect on the environment. Paper product is also another case because wood is being used for the production of papers, books, newspapers, which leads to deforestation and therefore should be shifted to digitalization and afforestation so as to save our planet. Current ICT systems rely on a series of varying products with several environmental characteristics. These include products such as PCs, servers, mobile phones, cables, and satellite, peripherals such as screens, printers, and scanners. Most IT products consist of components such as micro-chips, semiconductors, printed circuit board (PCB), cathode ray tubes and batteries, of which they have high environmental effects like for

example, the production of semiconductors causes significant amount of air emissions, acid fumes, volatile organic compounds and doping gases. (ITU-T, 2005.)

With the supply chain and use, IT peripherals are produced through global supply chain, and an example, a personal computer contains about 1500 to 2000 components produced around the world and transported from one region to another which causes a lot of environmental effects. ICT devices normally uses large amount of electricity ranging from about 150W per hour but the consumption rate of IT products are reducing with the integration of sensitive components for control. (UNGP 2011.)

5.2 Transportation medium

Transport medium refers to the means by which information lives from source to destination, which are classified in to three types such as wired, wires and satellite transmission systems. The production of these cables produces as much heat as producing a car, but the amount of heat it produces during information exchange is our primary concern. In ICT data travels in bits and bytes as electron flows from one terminal to another. The amount of heat produced during these process, amount to about 5% of the total heat production in the IT industry. (IPCC 2005.)



GRAPH 3: Wired Transmission Medium in It Industry (Vasile, 2008.)

5.3 How these equipment are being used

IT equipment are one of the most widely used equipment all over the world, ranging from security to transport either on land, sea, or air transportation. They link humans together forming a global village and easing communication. But during their usage, they consume lots of energy which in turn affects the environment and the world we are living in. From the Physical layer of the Open System Interconnect (OSI) layer, as shown below. The physical layer is the layer through which all end data communication passes through for transmission, it involves cabling, networking, interconnection, data encoding, physical medium attachments, transmission technique or broadband, physical medium transmission Bits and Volts. A review of the Application layer, also takes in to consideration, the end user devices in which the data is being received or transmitted. (Richard Harris, 2012.)

OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example	Central Device/ Protocols	DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	End User layer Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management	User Applications SMTP	G A T E W A Y Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	Syntax layer encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • Character Set Translation	JPEG/ASCII EBDIC/TIFF/GIF PICT	
Session (5) Allows session establishment between processes running on different stations.	Synch & send to ports (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.	Logical Ports RPC/SQL/NFS NetBIOS names	
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	TCP Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	F I L T E R I N G P A C K E T TCP/SPX/UDP	Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	Packets ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		Routers IP/IPX/ICMP
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	Frames ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control	Switch Bridge WAP PPP/SLIP	Can be used on all layers Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	Physical structure Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts	Hub Land Based Layers	

GRAPH 4. The OSI model (Layer 1 and 7). (Microsoft 2014.)

5.4 Disposal of ICT equipment

ICT equipment are a set of dangerous equipment when not handled with care. Recently, Africa has been the dumping ground for ICT devices, but most IT equipment and devices are mostly recycled. According to ICT policy on waste disposal, all devices and equipment used in Information Technology, especially those used for personal use such as PCs, or generally end user devices are very dangerous to the human system if no proper method of waste disposal is practiced. Most of them are non-bio-degradable which pollutes the environment and destroy the soil. Substances such as lead, arsenic, copper, which are found in all the PCs or end user devices you can find around, even in phones, destroy the human cells and also cause mutation. (WEEE 2008.)

The council policy relating to the reuse and recycling of ICT equipment seeks to ensure that there is compliance with the obligations under European, Asia and Africa Environmental Legislation, fulfils its commitment to the waste Reduction policy 2005 and sustainability policy 2000, meets software license obligations and reduce risk of sensitive data being released to unauthorized persons. ICT equipment must never be disposed of through other general waste routes. It is illegal to mix computer waste with General waste or to landfill untreated computer waste. According to Moore's law the performance of ICT doubles every 18 months. This results has shown to be correct, not only with processor speed but also memory capacity and data transmission speed. The main area of concern is the metal content of electronic waste. (Sara 2005.)

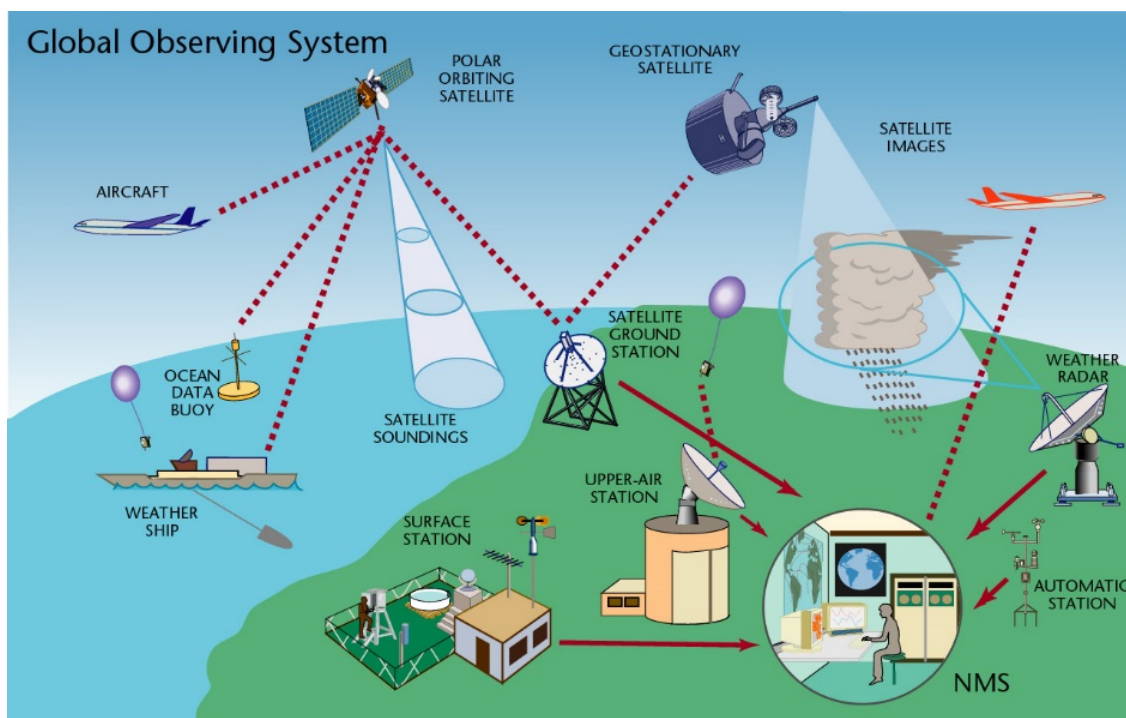
Moreover, virtualization also will lead to efficiency gain. Substituting information for materials and energy is also leading to environmental benefits in which substitution may be through dematerialization or virtualization through which digital information can be substituted from papers, and CDs. The Boston Consulting Group (BCG 1999) produced a comprehensive review of the impact of electronic media on paper which shows that there would be either direct or indirect pressures tending to lead to a reduction in paper demand because of technological advancement. (BCG 1999.)

6 USING INFORMATION TECHNOLOGY TO TACKLE CLIMATE CHANGE

Information and communication technology for environmental sustainability is a project which is aimed at tackling climate change and proving an emerging solution on how to deal with climate change, its effects and adapting to it outcome. Although some of these technologies mentioned have already been put in place, more still need to be done to improve on their sensitivity and improvements for efficiency and positive outcome. In October 2010, the International Telecommunication Union (ITU) reported that the number of internet user or generally users of ICT equipment have doubled and by it will undergo a geometric progression by 2020. In this effect, IT can be a vital tool to combat climate change in that, through ICT, information can easily get to a majority of the world within a short time interval. (GeSI, 2008 & ITU 2010.)

6.1 Using Information Technology for monitoring the environment

Information Technology is the only source for monitoring our planet. The equipment used in the monitoring process are shown in the diagram below in the Global Observatory system.



GRAPH 4: Global Observatory System (ITU & WMO 2008.)

The World Meteorological Organization is an IT based organization that aimed at monitoring the earth and other planets to know how they function and change with time. For the purpose of these thesis, the components of the GOS will not be studied individually, but will be studied as a system and how it is helping to mitigate climate change. The GOS uses soft wares, and equipment to monitor the world, in the domain of IT, its components are made of high efficient hard and soft wares to produce accurate results from experiments. Some of these equipment uses fuel for their energy supply, for which upgrading is currently going on to change their mode of energy supply so as to conserve energy to save our planet. The ICT systems that are involved in environmental and climate change monitoring , data sharing and early warning include, weather satellite that track the progress of naturally occurring events like hurricanes and typhoons, weather radars that track the progress of tornadoes and volcanoes, radio-based meteorological systems that obtain environmental information such as atmospheric composition.(UNFCCC & Bali 2007.)

In the domain of mobile communications to revolutionize African weather monitoring, weather stations have been built across Africa aid weather forecast and to increase the accuracy of forecast and sharing of information through mobile to the local population. The initial project was carried out in Kenya, United Republic of Tanzania, and Uganda. (Matthew, Barnett, McDonald & O'Brien 2001.)

6.2 Next Generation Networks and Energy Efficiency

Next Generation Networks (NGN) is one of the vital tools to combat climate change in the IT industry. Global migration to NGN could bring about a substantial reduction in power consumption and thereby reducing the telecommunication sector's contribution to global warming. NGN takes in to consideration the migration from analog through digitalization to wireless, to minimize transportation, use of materials for ICT equipment. It also improves the transport sector by upgrading from local transport systems to Intelligent Transport systems (ITS) in which the main focus of ITS is on the safety, management and efficiency of transport systems. ITS can also be used to reduce their environmental impact through which GPS used for navigation can reduce journey time. In ITS, two of the most promising technologies for improving energy efficiency are radio-frequency identification (RFID) and sensors which can be combined together to form a ubiquitous sensor network (USN) which can be used in many different environmental

applications such as temperature control, efficient control of heating and lighting, telemetry. (ITU-T 2008.)

Telepresence and High-performance Video-conferencing, is a service that provides the opportunity for companies to hold distance meetings and emergency seminars, which will increase productivity and save time by offering distance collaboration. I.T companies such as Microsoft, Google and Infosys have deploy one of the largest video conferencing facility in its headquarters. This services if made available to the local population, will reduce mobility of workers, and customers, thereby reducing transportation, cost of burning fuel, time to be invested in order duties and thereby saving the excess loss of GHG emissions to the atmosphere. Distance learning will also be enhanced by Telepresence and this boils down to the I.T companies to provide efficient quality of service to its customers. Telemedicine is one of the sectors in which telepresence will be highly needed in which doctors to carry out consultations, administer drugs and operate at a distance without the need to travel. (ITU-T 2007.)

6.2.1 Contribution of NGN to energy efficiency

Formally, telecommunication services where built on separate networks, with each of them having its own architecture. Services such as public switched telephone networks (PSTN), Global system for mobile communication (GSM) are some of the independent networks that needed synchronization. The internet has always been packet switched and not circuit switch meanwhile, an NGN can be used as a bases for all these networks. (ITU-T 2008.)

Table 2. Shows the difference between traditional networks and NGNs (Dieter & Ulrike 2003.)

TRADITIONAL NETWORKS	NGN
Dedicated networks (PSTN. GSM)	Sharing same networks.
Multiple circuit-switched and packet switched.	All Internet protocol (IP).
Different signaling systems, low digitalization.	Mixed between fixed/mobile.
Separate platforms for connection oriented and connection-less platforms.	Quality of service enabled.

Routing.	Multiple Routing of calls for resilience.
Classical switches.	Improved energy efficiency.

NGN are being developed using different technologies, some of which include wireless and mobile, fiber and cable, some early NGN implementations include field trials from operators such as BT in UK, NTT in Japan and AT&T in US. Next Generation Networks has a greater role in energy efficiency and thereby reducing the amount of GHG emissions there by reducing global warming. (ITU-T 2008.)

6.2.2 How NGN contributes to energy efficiency

The change to NGN is expected to cut down power consumption to a certain minimal level of about 25 to 35 % by introducing Internet protocol transmission as compared with PSTN. The migration to IP-based routing and switching systems has improved the efficiency of the core network over the past years and this is seen especially in voice transmission where digital compression techniques have provided about 70% reduction in transmission capacity. Furthermore, on RELAY, Green Benefits of mobile phone shows that by replacing the majority of desk phones with existing mobile phones, a 74 % saving in power consumption by telephony equipment can be achieved and finally, some new saving algorithms are coming up such as VoIP service and multimedia applications and this helps to prolong battery life. (ITU-T 2008.)

The introduction of multiple power modes will reduce energy consumption for example, full power, low power, stand-by mode and hibernation meanwhile, traditional equipment like Digital Subscriber Line (DSL) have only two power mode i.e. on and off. This variation in power mode will reduce energy wasting when the equipment is not in use. Based on this, the European Commission as part of the initiative to improve energy efficiency of electrical equipment, has published five different codes of conduct for ICT equipment, including the application of multiple power modes for broadband devices. (ITU 2008.)

6.2.3 NGN and Data Centers

With universal increase in the number of internet users, the energy increase in Data center and power consumption. A major component of this energy increase is in data centers (DCs) since more energy is needed to store and run applications and more over for the cooling systems of

server farms which represent two of the major ways in which ICT consume energy. Moreover, DCs growth is geometric with increase in online services. (John & Lippis 2010.)

6.3 Transmission medium

Transmission medium in IT refers to the means and method through which data is being interchange or move from source to destination. The area of transmission medium is one of the areas where IT industries are being caught from in the increment of global warming. Although its vision is simpered on a local scale, but it has a significant effect on the environment. With the discovery of coaxial cable, the IT sector have undergone a series increment to improve on its mode of data transmission from wired, wireless to satellite communication. Studies by the researcher from Consumer Electronic Association (CEA) shows that transmission medium contributes to about 2% of total global warming. Information Technology sick's to advance in data transmission in that it will develop and incorporate from coaxial to optical fiber communication for which large amount of data can be transported with little time.(Peter & Jennifer 2015.)

From the researcher's project on Optical fiber to the home (FTTH), the researcher found out that the best and fasted means of data transmission it by optical fiber since climatic conditions will affect the flow for wireless communication. Transmission medium affects climate change in that it produces heat due to flow of electrons. Moreover, in energy savings for transmission systems, all forms of broadband consume more power than narrow band. The introduction of low power modes should help reduce energy consumption in the future. The substitution of DSL by Optical transmission offers low energy because of its low signal level. (FTTH 2014.)

Table 3. Illustrate the amount of emission savings that could be achieved with NGN
(ITU-T SG15 2008.)

Project Description	Emission saving
NGN architecture	30 to 40 % compared to today's PSTN
Business travelling substitution by teleconferencing	98 % of average CO2 emissions compared to face to face meetings.
Telework program at the National Science Foundation	About 98 % GHG reduction per year
Power consumption in data centers	50% of consumption

From the Annex, if projects such as smart use of ICT in a global scale, Multiple power modes for broadband equipment, Unitary fixed/Mobile telephony office network, Fiber to the Home (FTTH), videoconferencing, e-paper, e-commerce and online media, will reduce the amount of GHG emission by the ICT sector.(ITU-T 2010.)

7 CONCLUSION AND RECOMMENDATIONS

ICT for environmental sustainability is a project whose aim was to outline the impact of Information Technology on climate change, from its contribution, through information distribution to mitigation. In addition to that, research on new technologies and applications that would assist the ICT sector in fighting climate change and a recommendation for new ideas to be brought forward for better understand and proving solution to save out natural and beautiful planet earth. The method by which ICT is helping to mitigate climate change, is by improving on Intelligent Transport System to reduce CO₂ emission , Telepresence and high-performance Video-conferencing to reduce mobility and time wastage, reducing GHG emission but private mobility and long distance travel , NGN and power efficiency.

More also, part of the responsibility of ICT is to make information available to the general public on how to live with, adapt to climate change and early warning signals for natural disaster management . Technical results provide an internationally agreed method of calculating two elements, the energy usage and carbon impact arising from ICTs lifecycle and the mitigation that can be achieved by replacing ICT services and devices for intensive fossil-fueled activities such as travel and transport, and through dematerialization. This work has an important bearing on current and future global agreements under which countries undertake commitments to reduce their overall GHG emissions.

Intelligent transport systems (ITS) is said to be well developed in regions like Africa so as to reduce traffic and less usage of fossil fuels which leads to huge emission of CO₂ to the atmosphere and also to improve on road transport network, method of waste disposal, deforestation. Next generation networks (NGN) require fewer switching centers, offer more continue over the next several decades and, despite technical advances, could increase the energy consumption of the global network. Although increasing the equipment replacement cycle will accelerate technological growth. Applications on GHG emissions by our mobile devices and early warning signals in those area vulnerable to disasters and natural disasters.

The researcher recommended for further studies and development to be carried out by anyone interested in nature conservation and global warming. Although the contribution of IT to climate change is minimal, but it is recommended and mandatory for more studies to be carried out at a speed of light in order to save our world.

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