Information and Communication Technology (ICT) Revolution: Its Environmental Impact and Sustainable Development

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Abstract: Our world's resources, and even the planet itself, are rapidly decaying faster than we can imagine. While many people debate the causes the effects are obvious to all: climate change, problem in the animal world, health problems and rising concern about sustainability. The question now is to what extent Information and Communication Technology (ICT) has impacted our world. In fact, what solutions has ICT provided to the prevailing problems in our world which we may refer to as development and at the same time what problems has ICT created in effect. Thus, it becomes imperative to ask: What are the environmental implications of the rapidly growing development and use of ICT with respect to sustainable development now and in the future? What policies should be implemented in the production of ICT infrastructures and use of IT for sustainable development? What implications or threat do the advanced ICT countries like United States, China and Japan present to developing countries especially in Africa, and India in terms of e-waste? These questions define the focus of this paper. The paper also contributes to awareness building in form of recommendations needed so that producers, marketers and consumers will consider environmental issues when producing, buying and finally disposing ICT components and resources.

I. INTRODUCTION AND MOTIVATION

Information Technology which in recent times has experienced a phenomenal growth both as an industry and in applications may be characterized by the use of computers, the Internet, cellular phones, e-business or commerce, video-conferencing, e.t.c. Although, the global society is excited and basking in the euphoria of the various use of ICT, both as a private and corporate applications with all the obvious benefits. However, the question of how ICT revolution affects the environment vis-à-vis sustainable development, which is one of the major twenty-first century challenges, has received limited attention to date. Underlying the driving force of ICT is computer technology--**hardware** which consists of all physical devices including cell phones and other electronic devices and **software** which consists of programmed instructions including embedded systems on which many electronic devices run. It is not an understatement to conclude that advances and diffusion of ICT have drastically changed the economic and social system of today, but the reverse effects also exist. That is, construction and development of ICT infrastructures is both energy- intensive and resource-intensive and the environmental impacts of the production, use, and disposal of ICT resources/materials are of great concern and not trivial.

ICT as an industry (hardware, software and services) has not only provided means to help generate, store, process and communicate information globally but has also pervaded all sectors of the economy, where they act as integrating and enabling technologies in order to improve productivity for sustainable development. However, the rapid advances in this industry have created some other environmental issues and concerns such as in energy, climate change, health sectors, and waste management and technology policies. All these require positive attention and support for sustainable development, hence the need for more research works into the roles and impact of ICT. ICT in its own right has developed very fast hence it has become part of development and as such there are many groups and initiatives working on ICT for sustainable development. These include International Telecommunication Union (ITU) which has a development group charged with ICT development and increased penetration. The Development Gateway Foundation, supported by the World Bank is a clearing house and repository for vast information on ICT and development, also the G8 instituted the Digital Opportunities Task Force (DOT Force) in 2001 to strengthen efforts on ICT and development. The basic facets of sustainable development include environmental, economic and social. It has thus become necessary for man to live in an environment where the economic and social needs are presently adequately without compromising the comfort of the future. Essentially, sustainable development presents the needs for providing solutions to the environmental, economic and social needs of the present without compromising the ability of the future generation to do so.

Therefore, even though the role of ICT has become pivotal to the realization of economic and social development. The control and management of ICT facilities has become very critical for the realization of sustainable development.

There have been various research contributions that have discussed the impact of ICT on the environment, social and economic development of the present generation in order to form a promising and interesting research path for this field. The fast growing trend in the production, use and disposal of ICT materials has called for more intensive awareness creation so as not to jeopardize future development. Some of these contributions are presented in the following.

The relationships between sustainable development and information dissemination mechanisms were examined on theoretical conceptual framework by (Jokinen et. al, 1998).This work first signaled the issues with information society and sustainable development. In 2000, Roome and Park(2000)presented a broad scope within which it can be concluded that IT has the tendencies to both negatively and positively impact the environment and thereby impacting on development sustainability. Reijnders and Hoogeven(2001) addressed the energy implications of e-commerce at the micro-level by quantifying the transport related energy savings in the case of Dutch online computer reseller and by assessing the extra energy of online buyers. In 2001, Heinomen et al presented some scenarios, criteria, and indicators meant to identify various environmental impacts inherent in information society. Sui and Rejeski(2002) analyzed the positive environmental impacts of the emerging digital economy as three Ds namely dematerialization, de-carbonization and demobilization. They pointed out that optimizing the environmental performance of an economy driven by information and knowledge creation was different from regulating one based largely on the processing material. Hesse (2002) analyzed the impact of e-commerce on freight transport, logistics and physical distribution regarding both Business-to-Business(B2B) and Business-to-Consumers(B2C) e-commerce. Romm et al.(2002) published a paper that claimed that recent reductions in energy intensity were connected to the growth in ICT and the Internet economy. They further explored the impact on Internet economy on manufacturing, buildings, and transportation. Macauley et al (2003) presented a model of costs and benefits of policies to manage e-waste, the focus was on a large component of the electronic waste stream namely computer monitors, the main issue here was environmental concern which was associated with disposal of the lead embodied in cathode ray tubes (CRTs) used in the manufacturing of most monitors. All of the previous research on ICT and the environment have discussed effects of ICT on the environment but have not adequately made far reaching recommendations that can ginger up the policy makers or shareholders to put up policies to enhance development sustainability vis-à-vis increasing growth in ICT implementations. This paper will consider the environmental implications of the rapidly growing development and use of ICT with respect to sustainable development now and in the future and suggest recommendations that can be formed into policies for implementation in the the production of IT infrastructures and use of IT for sustainable development.

II. SUSTAINABLE DEVELOPMENT AND PIVOTAL ROLE OF ICT

ICT has been an integral part of development. The debate to choose between ICT and other development imperatives has shifted from one of tradeoffs to one of complimentary[1]. ICT is now strongly recognized as an all-purpose enabling tool for development. Global development targets are embodied in the Millennium Development Goals(MDGs) briefly stated as follows:

III. MILLENNIUM DEVELOPMENT GOALS (MDGS)

1.Eradicate poverty and hunger

2.Achieve universal primary education

3.Promote gender equality and empower women

4.Reduce child mortality

5.Improve maternal health

6.Combat HIV/AIDS, malaria, and other diseases

7.Ensure environmental sustainability

8.Develop a global partnership for development

It is obvious that ICT by its performance and potential provides means to achieving the MDGs. The pivotal role of ICT in sustainable development can be anchored on the 4C's namely, Computing, Communications, Content, and human Capacity. When considering the use of ICT in development, it is known that even if hardware is free, communications, software, and training make ICT costly. With approximately two-third of the world economy based on services, and the rise of India, Philippines, and Singapore, and other nations as global ICT players, many developing countries have accepted ICT as a national mission. Within manufacturing and industry, ICT has an increasingly important role to play. For instance, during 1995-2002, when the US economy assumed and impressive growth, nearly one-third of the growth in productivity was attributed to ICT(World Bank Group Perspective, 2003). The following table indicates how ICT can help in achieving some of the points in MDGs.

	MDGs	Role of ICT
1	Eradicate poverty and hunger	Increase access to market information and reduce transaction costs for poor farmers and traders
2	Achieve universal primary education	Increase supply of trained teachers through ICT-enhanced and distance training of teachers and networks that link teachers to their colleagues.Broaden availability of quality educational materials/resources through ICTs
3	Promote gender equality and empower women.	Deliver educational and literacy programs specifically targeted to poor girls and women using appropriate technologies
4	Reduce child mortality	Enhance delivery of basic and in-service training for health workers using appropriate ICT tools
5	Improve maternal health	Enhance delivery of basic and in-service training for health workers using appropriate ICT tools
6	Combat HIV/AIDs, malaria, and other diseases	Increase monitoring and information sharing on disease and famine using ICT tools
7.	Ensure environmental sustainability	Remote sensing technologies and communications networks permit more effective monitoring, resource management, mitigation of environment risks.

Table1. Source: World Telecommunication Development Report 2003(ITU)

It needs to be noted from the table above that ICT may not be able to directly be used to realize the MDGs, rather its may be seen as enabler, primarily spanning several dimensions namely, efficiency and competitiveness, new business models and opportunities, and transparency and empowerment.

IV. ICT AND ENVIRONMENTAL CONCERNS

Information and Communication Technology is more than computers and by its performance and potentials has offered various options to help realize the Millennium Development Goals (MDGs). However, the development and usage of ICT is creating serious environmental concerns that need serious attention. The three categories of environmental challenges or risks identified with ICT products and infrastructure can be as follows:

i) Global resource depletion
ii) Energy use
iii) The emission of toxic substances over the lifecycle (production, use, disposal).

This paper will consider these three categories and finally proffer a list of recommendations that we think are worthy of note.

i).Global Resource Depletion: In the pursuit of sustainable development, the plans or strategies must consider the use of natural resources with respect to the consequences for the future generation and without exploitation. ICT has grown to be part of our development. But the question is how sustainable is that development in the light of the various environmental threats (global warming, ozone layer depletion etc) facing the world today. In the production of the various microelectronics components that make up the ICT infrastructures, the level of natural resources used is significant due to highly organized structure of the components. For instance, total resource consumption during the lifecycle of a single 32 MB DRAM memory chip of approximately 2 grams amounts to: 1.6 kg of fossil fuels, 27 g of various chemicals, 700 g of elemental gases, and 32 kg of freshwater. Furthermore, 41 MJ of energy per chip is needed in the production chain of silicon wafers (Williams *et al.* 2002). For a complete personal computer including CRT-monitor, the input of abiotic raw materials is up to 1500 kg (Turk 2003).

ii).Energy Use: Considering the massive production of ICT facilities and components, the level of energy consumption has in turn increased over the years. For instance, in Germany the ICT-related consumption of electric energy has risen up to 38 TWh in 2001, which is 7.1% of total electricity consumption (Williams et.al. 2002). According to Williams(2004), the total energy and fossil fuels used in producing a desktop computer with 17-inch CRT monitor are estimated at 6400megajoules(MJ) AND 260kg, respectively, this indicates that computer manufacturing is energy intensive. With the extensive use and production of ICT infrastructures, the energy consumption is increasingly phenomenal.

iii).Toxic Substances Emission (Production, Use and Disposal): The rapidly growing amount of ICT equipment is causing increasing problems in the disposal (end-of-life) phase of the electronic waste. The annual amount of scrap from electronic equipment is estimated to be 68,000 metric tons in

Switzerland and 2.1 metric megatons in the United States (EMPA 2004a; USEPA 2002).

Recycling or disposal of computers and telecommunication hardware is problematical, because electrical and electronic equipment includes a multitude of components causing human and ecological risks, such as heavy metals and halogenated organic compounds. In case of inadequate disposal or recycling, the emission of toxic substances from electronic waste can pollute water, soil, and air, and harm human health. The technically complex problem of electronic waste disposal is not taken care of equally well in all parts of the world.

Electronic waste or E-waste is the most rapidly growing waste problem in the world. It is a crisis not only of quantity but also a crisis born from toxic ingredients – such as the lead, beryllium, mercury, cadmium, and brominated flame retardants that pose both an occupational and environmental health threat. But to date, industry, government and consumers have only taken small steps to deal with this looming problem. Figure 1 and Figure 2 below show the menace of computer junks

Fig.1 Source:New York Times Company)

Fig.2(Source:New York Times Company)

In general, electronic equipment is a complicated assembly of more than 1,000 materials, many of which are toxic to humans. For example, several of the most commonly used items include:

_ **lead and cadmium** in circuit boards,
_ **lead oxide and barium** in computer monitors' cathode ray tubes,
_ **mercury** in switches and flat screens, and
_ **brominated flame retardants** on printed circuit boards, cables and plastic casings.

Comprehensive health impacts of combinations of these and other chemicals in the products are not known. However, it is widely known that the production of computer components—such as, semi-conductors, printed circuit boards, disk drives and monitors—use significant amounts of toxic gases, acids and industrial solvents. While there is a perception that high tech is a "clean industry," the majority of high tech assembly workers–often immigrant, women of color–work in a context with hazardous chemicals and some of the lowest paying jobs in the industry. These workers experience disproportionate impacts on their health compared to employees in other sectors. For example, many workers in chip manufacturing are reporting cancer clusters and birth defects.

Source: Silicon Valley Toxics Coalition 2002 (see http://www.svtc.org)

Fig.3 Computer and Human Health

Both the hazardous and non-hazardous waste at the end of a high tech product's use—often referred to as "e-waste"—presents environmental concerns. In the U.S. only 14% of computers are recycled or remanufactured, with the remaining 86% going to hazardous waste landfills (46%), solid waste landfills (25%), and incineration facilities (15%).

V. RECOMMENDATIONS

This paper intends to proffer a 3-level recommendations namely, national government level, organizations/companies and non-governmental organizations (NGOs), and universities and research institutes. Some of the recommendations are as follows:

VI. NATIONAL GOVERNMENT

i). To initiate necessary legislative policies meant to regulate the sites of base stations for transmissions and determine safe radiation levels.

ii).To create an up to date database of scientific evidence of dangers or health risks arising from the make, use and disposal of ICT infrastructure elements.

iii).To cooperate with other organizations such as NGOs, to develop information programmes that can provide solutions or answers to some of the concerns arising from the impact of ICT on the environment.

iv).To initiate projects for creation of integrated systems aimed at proper disposal of ICT waste which include different parts of computers, cell phones components, etc.

v). To use appropriate means of information, including sign boards, to inform and warn residents in the neighbourhoods where there are mobile telephony stations of the existence of such stations and of any related risk,

vi). To urge information departments to cooperate and coordinate with departments of environment, health and telecommunications, and with nongovernmental organizations, to support the dissemination of environmental information in all its forms: reading material, radio and television, the internet, etc. with a view to keeping people informed of the health and environmental impact of using ICT equipment, and of the means of minimizing the resulting risks.

VII. PRIVATE AND NON-GOVERNMENTAL ORGANIZATIONS

i) To support the implementation of integrated programmes for processing and safe disposal of ICT waste in their community, to establish the supporting institutional and legal frameworks for this purpose, and to consider the implementation of such programmes on a priority basis.

ii).To organize seminars and workshops to enlighten and educate people on the environmental impact of electronic wastes proffer possible solutions of management.

iii). To produce and disseminate scientific periodicals, in local languages focusing on health and environmental risks associated with ICT.

iv). To initiate programmes that ensure that safety and prevention measures are being applied to control exposure to occupational and environmental risks related to the work with ICT equipment are in place and implemented.

VIII. UNIVERSITIES AND RESEARCH INSTITUTES.

i). To give special attention to research on health and environmental impact of ICT, including the Internet and mobile telephony.

ii). To direct part of their research work to health and environmental impact of ICT on living organisms, including micro organisms, especially the effect of such impact on the ecological balance and human beings.

IX. CONCLUSIONS

ICT as an industry has not only provided means to help achieve MDGs and communicate information globally but has also pervaded all sectors of the economy, where they act as integrating and enabling technologies in order to improve productivity for sustainable development. However, the rapid advances in this industry have created some other environmental issues and concerns which have be looked into in order to have more benefits of ICT than its woes.

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