The ICT Sector and the Global Connectivity System

A sustainable development overview

Tony Vetter,
with Heather Creech

November 2008

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1.0 Introduction

In 2007, IISD published a collection of papers on Internet Governance and Sustainable Development: Towards a Common Agenda, as a preliminary investigation into the linkages between these two domains. In undertaking this review, we realized that stakeholders in these domains held different perspectives on what constituted the "Internet sector" and, possibly more broadly, the "information and communications technologies [ICT] sector." Without greater clarity and definition provided by a sector approach, we found it problematic to begin to address questions around who would be in a position to work for greater synergies between ICTs, the management of the infrastructure and content we know as the Internet, and their role in contributing to, or moving the world further away from, sustainable development. This broad group of actors involved in the production of hardware, software, communications infrastructure, standards, policies, content, collaboration and networking is potentially more complex than other sectors with which the sustainable development community has engaged in the past, including extractive industries, the energy sector, agriculture, health and so forth. Participation from the ICT industry in the World Business Council for Sustainable Development has shifted away from the traditional hardware and software manufacturers; but has increased slightly from the telecommunications sector. Within one of the few sustainable-development-focused ICT industry associations, the Global E-Sustainability Initiative (GeSI), there is room for "any company or organization which, as a principal part of its business, provides a service for the point to point transmission of voice, data or moving images over a fixed, Internet, mobile or personal communication network, or is a supplier of equipment which is an integral component of the communication network infrastructure,"[1] but not necessarily room for those that serve to manage the infrastructure through the development of standards and protocols, or for those who provide content and applications as part of their social engagement within and through the infrastructure. This paper is our first effort to gain greater clarity on what more broadly constitutes the ICT sector and its role in sustainable development.

Evidence has been mounting that the ICT sector, through the innovation and supply of ICTs, is making a considerable contribution to overall economic performance. Policy-makers and analysts want to understand and measure the importance of the activities of the ICT sector in order to properly inform policy-making that could support, and possibly expand, the realization of these benefits. However, understanding and measuring the ICT sector has been challenged by the fact that ICT production takes place in many industries, either as a principal or secondary output. The need for useful and comparable statistics has therefore necessitated converging on narrow definitions of the ICT sector.

[1] GeSI membership statement, http://www.gesi.org/index.php?article_id=9

Practical consideration of the equally profound influences that ICTs are having on global prospects for achieving sustainable development has also tended to be more specifically focused as well. Practitioners of ICT for development (ICT4D) focus on the potential for ICTs to improve socio-economic conditions, particularly in developing countries. Many practitioners have taken a tools and capacity building approach, based on intersections of ICTs and other sectors—ICTs for health; for education; for governing; and so forth. Those considering the role of ICTs and issues of environmental sustainability have either focused on their potential role in terms of environmental management applications, or the negative impacts of electronic waste. But these narrower approaches may have, as a result, missed the sustainable development implications of how the sector as a whole is transforming society, for better or worse.

To date, consideration of the *full range of actors, applications and actions of the ICT sector* within the broader context of sustainable development has been limited. Those currently working on sustainable development need a way of describing the ICT sector in a manner that helps them identify the parameters directing its activities so they can see more clearly how the sector could be influenced, shifted or repositioned to better contribute to a global transition to sustainability. This paper begins, we hope, to lay the foundation for such a broader

First, our world is becoming instrumented: The transistor, invented 60 years ago, is the basic building block of the digital age. Now, consider a world in which there are a billion transistors per human, each one costing one ten-millionth of a cent. We'll have that by 2010. There will likely be 4 billion mobile phone subscribers by the end of this year... and 30 billion Radio Frequency Identification tags produced globally within two years. Sensors are being embedded across entire ecosystems-supply-chains, healthcare networks, cities... even natural systems like rivers. [Note: Another way of expressing this is that each human being, on average, is supported or supplemented by US$1,000 worth of transistors. (sns)]

Second, our world is becoming interconnected: Very soon there will be 2 billion people on the Internet. But in an instrumented world, systems and objects can now "speak" to one another, too. Think about the prospect of a trillion connected and intelligent things-cars, appliances, cameras, roadways, pipelines... even pharmaceuticals and livestock. The amount of information produced by the interaction of all those things will be unprecedented.

Third, all things are becoming intelligent: New computing models can handle the proliferation of end-user devices, sensors and actuators and connect them with back-end systems. Combined with advanced analytics, those supercomputers can turn mountains of data into intelligence that can be translated into action, making our systems, processes and infrastructures more efficient, more productive and responsive-in a word, smarter.

Sam Palmisano, Chairman of IBM, to the Council on Foreign Relations, November 6, 2008 understanding of what the ICT sector is, and why those currently working on sustainable development [the "SD Community"] should pay closer attention to how the sector is evolving.

2.0 The Challenge of Defining the ICT Sector

One factor contributing to more narrow and bifurcated thinking on the role of ICTs in sustainable development observed to date is that economics-based methodologies for describing, categorizing and targeting sectors draw their boundaries based on groupings of discrete goods and services. This promotes consideration of the ICT sector simply in terms of the discrete tools it produces. Such a framing impedes attributing to their point of origin the countless influences that ICT innovation has on issues of sustainability beyond the traditional border of the ICT sector. This in turn limits thinking on how these influences could be mitigated or guided towards contributing positively to achieving sustainable development. An alternative viewpoint on the ICT sector is needed that transcends traditional sectoral boundaries in order to facilitate a thorough understanding of these influences and the actors shaping them.

The permeation of ICTs into more and more of our social processes has made it increasingly difficult to draw acceptable boundaries around all actors and activities that play roles in the complex ICT innovation, supply and demand dynamic without blurring established sectoral boundaries and measurement practices. With evidence mounting of the significant role ICT diffusion has been playing in economic growth, economists have been keen to quantify this influence in order to single out those responsible factors for focused investment and policy support. Such efforts however have succumbed to narrow definitions of the ICT sector. For example, the member nations of the Organisation for Economic Co-operation and Development (OECD) settled on an initial definition of the ICT sector in 1998 which was "limited to those industries which facilitate, by electronic means, the processing, transmission and display of information, and it excludes the industries which create the information, the so-called 'content' industries."[2] Unfortunately such narrow treatments for the convenience of simplifying the accounting of economic contribution propagate the view of the ICT sector as an island onto itself—as being solely the domain of manipulating, transmitting and deciphering "1s" and "0s"—making it a greater challenge to shed light on trends and practices inherent to the supply and demand dynamics between the ICT sector core and its fuzzy periphery. Figure 1 helps to illustrate how the 1998 OECD deliberations arrived at their preliminary definition of the ICT sector.

[2] OECD (2007). Guide to Measuring the Information Society. Paris: OECD. Retrieved July 3, 2008 from http://www.oecd.org/document/22/0,3343,en_2649_34449_34508886_1_1_1_1,00.html

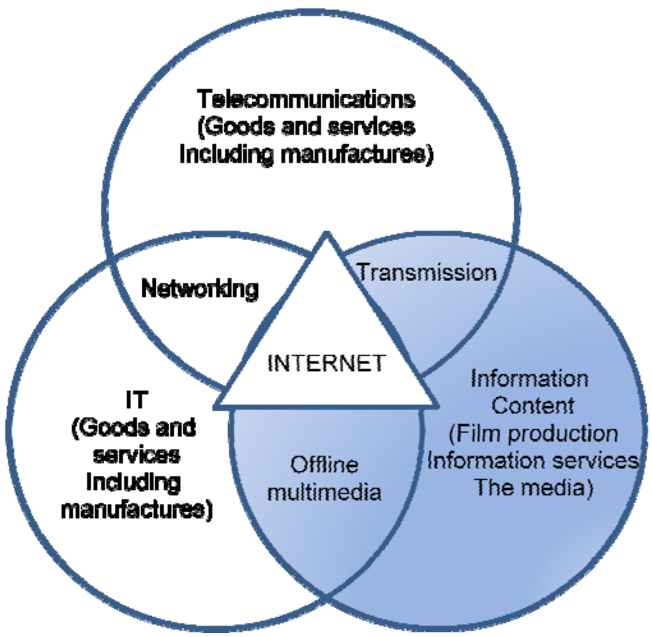

Figure 1: Overlap between the information technology, telecommunications and information content activities of firms (adapted from a Finnish model)[3]

In general terms the OECD negotiations arrived at the position that "the ICT Sector can be viewed as the activities which fall into the union of the Information Technology and Telecommunications activities in the diagram above. It includes therefore the intersections between them and the Information Content activities (all activities coloured white). However it excludes those Information Content activities which fall outside those intersections (all activities not coloured white); that is, those which have no direct ICT association."[4] The idea of an

[3] Ibid.
[4] Ibid.

"information economy" (represented by all three activities) was agreed to consist of a content sector (produces content) and an ICT sector (moves and displays content). The concept of an "information society" was therefore agreed to signify social impact of the "information economy."

Aside from some minor revisions in 2002, thinking on these preliminary notions of an ICT and content sector were not revisited by the OECD until 2006. By this time ICTs had become increasingly "embedded into a growing number of products produced by a variety of industries" and debates symptomatic of this trend emerged in the deliberations, exemplified by basic questions such as:[5]

- Should the scope of the definition be limited to industries producing products intended to fulfil the functions of information processing and communication, or should the definition be extended to include industries producing products that use electronic processing to detect, measure, record or control a physical process?
- If a choice was made for the more inclusive approach, how could the scope of the definition be rationalized given that more and more products incorporate technologies that use electronic processing?

In the end the OECD deliberations agreed that it would become too difficult to distinguish industries that employ ICTs in the manufacture of measuring, testing, navigating and control equipment in a significant way from those that do so in an incidental way and agreed to drop those activities from the ICT sector category.

This brief example from the OECD deliberations illustrates how the debates regarding the economic boundaries of the ICT sector easily become convoluted. As these technologies continue to transform our world, issues linger on the horizon that will continue to challenge the separation of an "ICT sector" from other sector activities, most notably the content sector. For example: how do you distinguish between transmission activities and content development activities in an increasingly Web 2.0 world?; is the intervention of a "publisher"—i.e., of a commercial publishing business—a precondition for recognizing output as "content" that has economic value (as opposed to content being uploaded by individuals on sites such as YouTube)?; will the industry emerging around the "Internet of Things" (a wireless and self-configuring, network between objects)[6] be considered part of the ICT sector?; what about businesses developing intelligent transport solutions or smart building technology? In light of the realities facing economists struggling to categorize and measure these economic activities one can only sympathize with the increasingly impossible task they face. However, this need not be the path the SD community follows to get a better handle on the ICT sector. Economists are first and foremost concerned with quantifying economic activity which, as has been witnessed,

[5] Ibid.

[6] Internet of Things, Wikipedia, http://en.wikipedia.org/wiki/Internet_of_Things (last accessed July 8, 2008).

necessitates creating artificial boundaries that cut across important links of influence and interdependency.

Two alternative ways of looking at the ICT sector have emerged that could help with conceptualizing it beyond traditional sectoral boundaries. The first is to approach the availability and use of ICTs as an index of economic development. The second would be to view ICTs and their stakeholders as a global system.

3.0 The "E" Index Approach

E-readiness, as defined by the Economist Intelligence Unit, is "the 'state of play' of a country's information and communications technology (ICT) infrastructure and the ability of its consumers, businesses and governments to use ICT to their benefit. When a country does more online—or, as is increasingly the case, wirelessly—the premise is that its economy can become more transparent and efficient."[7] What is important within this definition is the consideration not only of the infrastructure—the availability of the core hardware, software and telecommunications components—but also of a broader group of stakeholders contributing to and benefiting from ICTs. Those factors considered in preparing the ranking—the quantitative and qualitative criteria—shed further light on the roles and contributions of various stakeholders beyond the narrow definitions of the ICT sector. There are over two dozen indices that attempt to describe a broader picture of the ICT sector and its place in economic and social development. A useful comparison prepared in 2005 by Bridges.Org can be found at http://www.bridges.org/publication/128. From their perspective, "it means considering whether the necessary infrastructure is in place, but also looking beyond that to whether ICT is accessible to the population at large and whether there is an appropriate legal and regulatory framework to support its use."

[7] The Economist Intelligence Unit. The 2007 e-readiness rankings: Raising the bar. EIU 2007

4.0 The Global Connectivity System

The second approach is to view ICTs and all the related actors and stakeholders as a global system. The definition of a system can be as simple as "a set of interacting or interdependent entities … forming an integrated whole."[8] But this simplicity supports a focus on the unique institutions and norms that have played vital roles in the evolving activities of the ICT sector, rather than the more restrictive view on the products and services those activities produce. It is these institutions and norms that have shaped the behaviour of the entities that carry out their activities within the system, as well as define their interdependence as a system. Many such entities would not have been considered a part of an ICT sector based on a more narrow definition. However there can be no doubt as to the roles they play in shaping the activities of the Global Connectivity System including its innovation, thereby justifying their inclusion as players in determining the influence of the system as a whole.

The traditional definition of the ICT sector of course encompasses a wide variety of manufacturing, software and service industries responsible for producing ICT products and services. The manufacturers of components and circuit boards, which in turn feed the manufacturers of computers, peripherals, data storage devices, networking

We have refined our notion of connectivity. It remains a defining indicator of how a country's population is able to access the Internet and digital channels; the more telephones and Internet accounts a country has, the easier that e-readiness is to achieve. But it is also true that certain types of connectivity are proving better than others in enabling e-readiness. Broadband Internet access enjoys greater influence in 2007—not only its penetration, but also its affordability to households. We have also eliminated fixed-line phones as an indicator and increased the weight of mobile penetration, as mobile phones are generally cheaper, easier to access and, with text messaging and mobile commerce applications, increasingly powerful digital devices.

Another key refinement has come in our analysis of the **part that legal structures play** in creating e-ready economies. We have also placed greater emphasis on the **role of governments** in fostering digitalisation, both as providers of vision and policy direction, and also as creators of digital channels for their constituents.

Lastly, we have re-focused the consumer and business adoption category to evaluate the utilisation of digital channels by individuals and businesses. We have also slightly increased its weight relative to connectivity and other categories in recognition of the fact that, **ultimately, it is actual users who determine a country's e-readiness, not its networks.** [Emphasis added]

Source: The Economist Intelligence Unit, 2007

[8] System, Wikipedia, http://en.wikipedia.org/wiki/System (last accessed Nov 26, 2008).

devices, communication devices and entertainment devices—consumer, business and military—include many recognizable company names.[9] The broad categories of software industries include application software, business software and services, multimedia and graphics software, and technical and system software—both home and enterprise—also include many well known company names.[10] The industries using many of these products to offer services include CATV systems, diversified communication services, healthcare information services, information technology services, Internet information providers, Internet services, security software and services, telecom services and wireless communications—adding many additional household names to the ICT sector ranks.[11]

The absence of consideration for the institutions and norms that have shaped the behaviour of these ICT sector entities becomes glaringly obvious when one considers the crowning achievement of the ICT sector, that being the global communications infrastructure. Who among these entities is responsible for the distribution of Internet IP addresses;[12] Internet domain name and management of the Internet root servers;[13] the development and publishing of communication, networking and Internet standards?[14] What entities coordinate all of the policy discussions involved with arbitrating and agreeing on these functions?[15] Given the trans-border nature of the global communications infrastructure, what international organizations oversee or host policy discussions between nation states on its intersection with other issues of common

[9] Acer, Alcatel-Lucent, Apple, Boeing, Broadcom, Canon, Celestica, Cisco, Dell, EMC, Flextronics, GE, HDS, Hewlett-Packard, Honeywell, HP, IBM, Intel, Juniper Networks, Lockheed Martin, Logitech, Matsushita, Motorola, Nikon, Nokia, Nortel, Philips, Polycom, Qualcomm, Samsung, SanDisk, Sony, Texas Instruments and Xerox, only to name a few.

[10] Corel, EDS, Electronics Arts, IBM, Infosys, Microsoft, Oracle, Sun Microsystems, Vmware and Wipro, only to name a few.

[11] Accenture, AT&T, Baidu, BCE, BT Group, Cerner, Check Point, China Mobile, China Telecom, Comcast, Computer Sciences Corp., DST Systems, Eclipsys, EDS, Expedia, France Telecom, GE Healthcare, Google, IBM Global Services, McAfee, Microsoft, Nippon, Priceline, Research in Motion, Siemens, Symantec, Telefonica, Time Warner Cable, Verizon, Vodafone and Yahoo, only to name a few.

[12] The Internet Corporation for Assigned Names and Numbers (ICANN) assigns IP addresses to Regional Internet Registries (RIRs), who in turn assign them to Network Information Centres (NICs), or Internet Service Providers (ISPs), or edge networks.

[13] ICANN assigns Top Level Domains (TLDs) to registrars who in turn allocate domain names. The Internet root zone is managed by the Internet Assigned Numbers Authority (IANA), a role performed by ICANN.

[14] Key organizations involved in global communications and Internet standards include: Institute of Electrical and Electronics Engineers (IEEE), International Telecommunication Union (ITU), World Wide Web Consortium (W3C), Internet Engineering Task Force (IETF), Internet Architecture Board (IAB), The Internet Engineering Steering Group (IESG), Internet Research Task Force (IRTF), International Organization for Standardization (ISO), European Telecommunications Standards Institute (ETSI), American National Standards Institute (ANSI) and Telcordia Technologies, among others.

[15] U.S. Department of Commerce maintains arms length oversight of ICANN. In the case of standards each of the bodies have various views of their own and each other's roles, which do not agree, but they nonetheless attempt to cooperate.

concern such as:[16] economic development; environmental impact; trade; standards and regulations; intellectual property; human rights and security; and governance of the Internet? Who represents the oversight interests of the general public on these issues?[17]

The answer is that none of the traditional ICT companies is fulfilling any of these roles, considered in many cases vital to the functioning and stability of the global communications infrastructure, other than through voluntary contributions to some of the collaborative organizations that do. And yet many of the organizations that do fulfill these roles have a profound influence on the activities of the Global Connectivity System and its innovations. As a case in point, the Internet would never have come into being, and experience the exponential growth it has, had it not been for the voluntary efforts of the technical community which established the collaborative organizations (see footnote 14) whose formation was based on norms intent on ensuring—through the promotion of open standards free of patent protection, and principles that placed much of the control of Internet functionality in the hands of the end-user—that anyone who wanted to help build the Internet was free to do so. It is widely acknowledged that these norms originated from the academic hacker subculture of the 1960s which espoused:[18] the sharing of software; freedom of inquiry; hostility to secrecy; information-sharing as both an ideal and a practical strategy; emphasis on rationality; and a distaste for authority, among other traits. These norms also expressed themselves in many end-user activities that have gone onto have significant influence over the activities of the system in their own right. For example the sharing of software was eventually institutionalized as the free software movement in 1983. That movement later spun out the open source software (OSS) movement in 1998, which has gone on to become a significant end user institution of the Global Connectivity System and has had significant influence in ICT innovation. Linux, a well-known operating system platform that was created initially by Finnish programmer Linus Torvalds, which was developed almost entirely in "open source" software circles, is now shipping on a significant percentage of PCs worldwide (see Figure 2).[19]

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[16] World Economic Forum (WEF), Global Alliance for Information and Communication Technologies and Development (GAID), Organisation for Economic Co-operation and Development (OECD), World Bank, InfoDev, United Nations Environment Programme (UNEP), World Intellectual Property Organization (WIPO), United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Office on Drugs and Crime (UNODC), United Nations Conference on Trade and Development (UNCTAD), World Trade Organization (WTO) and the Internet Governance Forum (IGF), among others.

[17] Many civil society organizations are actively trying to represent the interests of the general public on many key ICT policy fronts. They include: Berkman Center for Internet & Society, Electronic Privacy Information Center (EPIC), Association for Progressive Communications (APC), Global Internet Policy Initiative (GIPI), Basel Action Network, Greenpeace, LIRNEasia, International Development Research Centre (IDRC), International Institute for Sustainable Development, TakingITGlobal (TIG), Orbicom, International Institute for Communication & Development (IICD), Creative Commons (CC), Software Freedom Law Center (SFLC), League for Programming Freedom (LPF), Electronic Frontier Foundation (EFF), Center for Democracy and Technology (CDT), Reporters Without Borders (RWB) and the Open Source Initiative, among others.

[18] Levy, S. (1984). *Hackers. Heroes of the computer revolution.* Champaign: Project Gutenberg.

[19] Iansiti, Marco and Gregory L. Richards (2005).

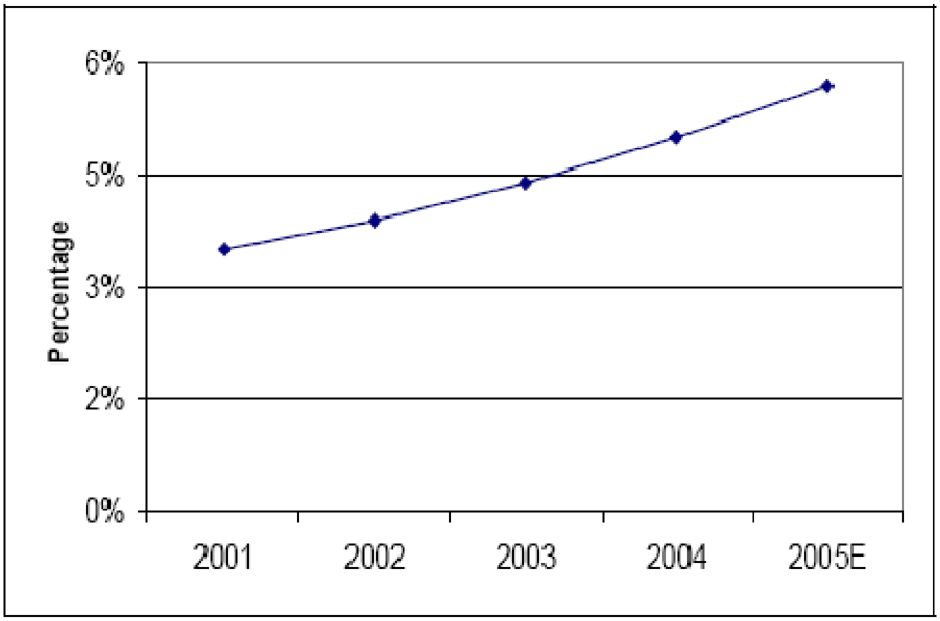

Figure 2: Growth of PCs that ship with the Linux platform 2001–2005(E)

Of course the hacker sub-culture itself continues in the form of end-user institutions known as Black-hat hackers (malicious or criminal hackers); ethical hackers (more commonly referred to as white hats); and the more ethically ambiguous (grey hats), many of whom are organized to the extent that they hold conferences, inform policy and share best practices in the domain of ICT security as a result of their exploitation of, and benevolent efforts to improve, the security of computers and networks.

Based on these acknowledgements of the critical roles these entities play in the activities of the Global Connectivity System and its innovations—roles that normally would not be considered part a traditional ICT sector definition—a picture now emerges of a whole system of actors and actions. In Figure 3, the diagram depicting the ICT sector as a Venn diagram of information technology, telecommunications and information-content-producing industries has been augmented to show the Global Connectivity System that includes institutions involved in the allocation of Internet resources, Internet standards, networking standards, international organizations, civil society organizations and end-user institutions.

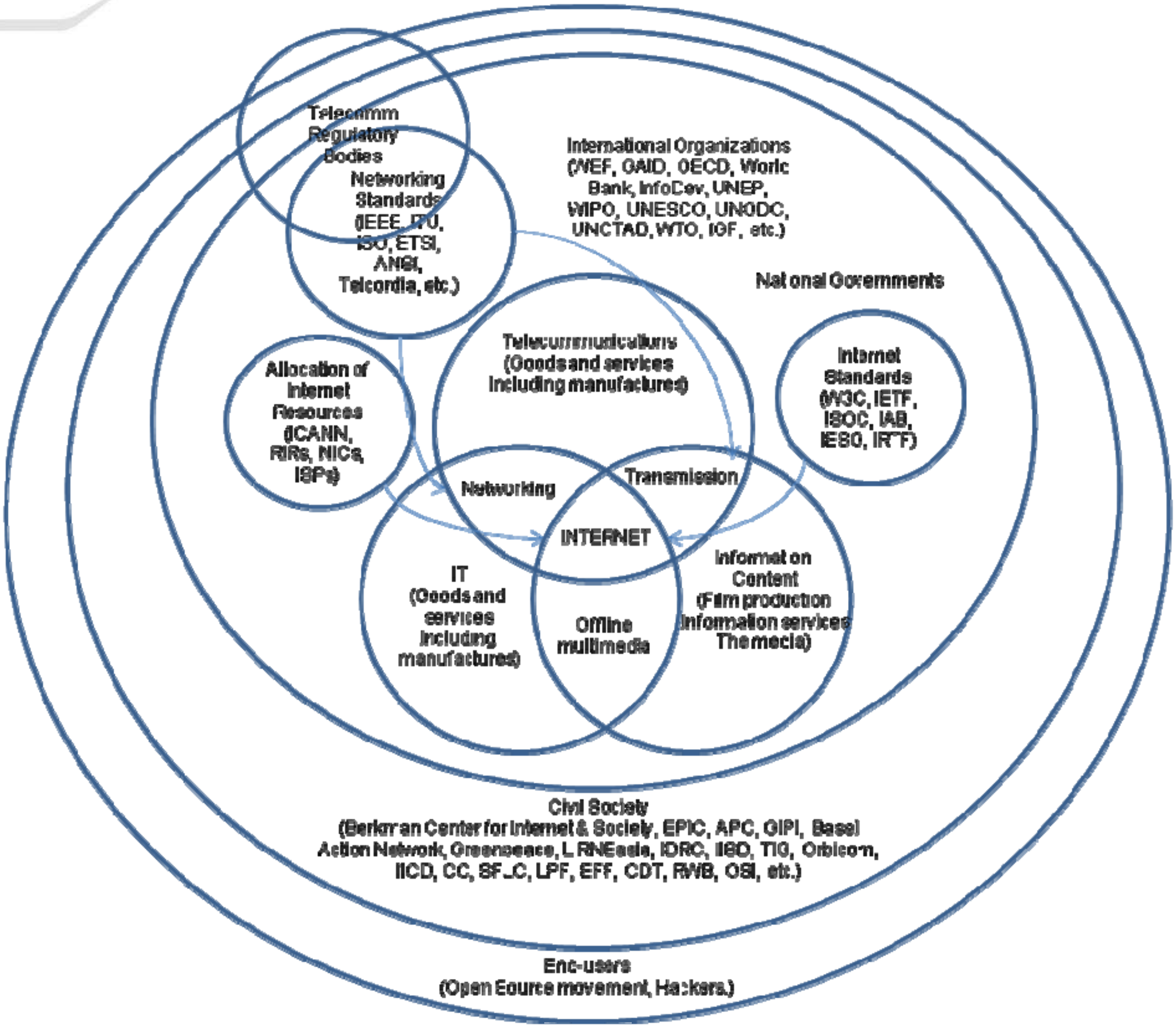

Figure 3: The Global Connectivity System

This depiction of the Global Connectivity System is far from static. Several tensions have been created by the emergence of the Internet and global communications, which are serving to draw in additional players. The proliferation of the duplication and distribution of culture in general as enabled by the Internet, more generally referred to as open source culture, has pulled content-producing industries not previously considered a part of the ICT sector into the system. With their business models under threat by the open sharing of digital content over the Internet by end-users, content-producing industries have pushed back on the open source culture supported by the Internet by not only lobbying for increasingly restrictive intellectual property rights (IPRs) and policies governing access to copyrighted content at the national level, but also engaging international institutions, such as WIPO, and drawing policy-makers at both levels into the Global Connectivity System. In parallel, digital content producers have also been working with members of the traditional ICT sector to develop digital tools to help with their cause and convince policy-makers of the tractability of their position. This has led to the emergence of Digital Rights Management (DRM) applications which attempt to contain end-user access to digital content to within the boundaries defined by copyright laws. They have also engaged policy-makers to attempt to compel Internet service providers (ISPs) to take on responsibility for policing the sharing of copyright protected digital content over their networks. In response, many civil society organizations have taken up the cause of arguing for less restrictive IPRs on the basis that society as a whole would benefit greatly from the innovation that would be stimulated by having more information and culture as part of the commons. For example Creative Commons (CC) is a non-profit organization devoted to expanding the range of creative works available for others to build upon legally and to share.[20]

ICT manufacturers, application developers and service providers have not only been subject to such pressure from the content industries. They have also been under pressure to collude in infringing on civil liberties of end-users. Several emerging markets want to capitalize on the benefits that come from the Internet in terms of promoting market innovation and economic growth, but want to maintain control over social discourse, and the free flow of ideas in the name of civil stability. Notable examples include the assistance some ICT hardware and service providers have given to China in the building of their "great firewall" or in releasing the identity of subscribers to the authorities. Even in democratic countries there is great concern regarding governments' actions to monitor communication occurring over the Internet in the name of domestic security and a "war on terror." Such interest on the part of the private sector and governments to challenge the principles on which the Internet has evolved to date have led to the emergence of civil society institutions that have been created for the sole purpose of resisting such pressures. To name only one of many examples, the Electronic Frontier Foundation (EFF) has gone head-to-head with government agencies and the private sector on behalf of end-users on a broad spectrum of rights issues in cyberspace including: file-sharing; Digital Rights Management (DRM); Internet governance; privacy and surveillance; and, spam and intellectual property rights. Many civil society organizations are also working on the formulation of an Internet Bill of Rights meant to bring existing rights frameworks, including the universal declaration of human rights, into the digital age.

The implications of production and consumption of ICTs have also served to draw international organizations and civil society institutions into the global connectivity system. A main driver for the involvement of these institutions has been concern for the disposal of electronic waste in many developing countries, where citizens make a living from the crude recycling of ICTs, exposing themselves and their surrounding environment to hazardous materials. In 2002 the EU implemented a Waste Electrical and Electronic Equipment Directive designed to make

[20] Creative Commons, Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Creative_Commons

equipment manufacturers financially or physically responsible for their equipment at its end-of-life under a policy known as "extended producer responsibility." This directive along with another, the EU's Restriction of Hazardous Substances Directive (RoHS), have had a significant impact on how ICT manufacturers operate around the world. Parties to the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal also recently focussed their efforts on electronic waste in 2006. Civil society institutions such as the Basel Action Network (BAN) have launched campaigns like their E-Waste Stewardship Project to ensure that exports of hazardous electronic waste (particularly from the USA) to developing countries, exposed by BAN, are eliminated and replaced with producer responsibility and green design programs/legislation.[21] Greenpeace has also been very aggressive in using their Guide to Greener Electronics to influence ICT hardware manufactures to change their product designs and processes.

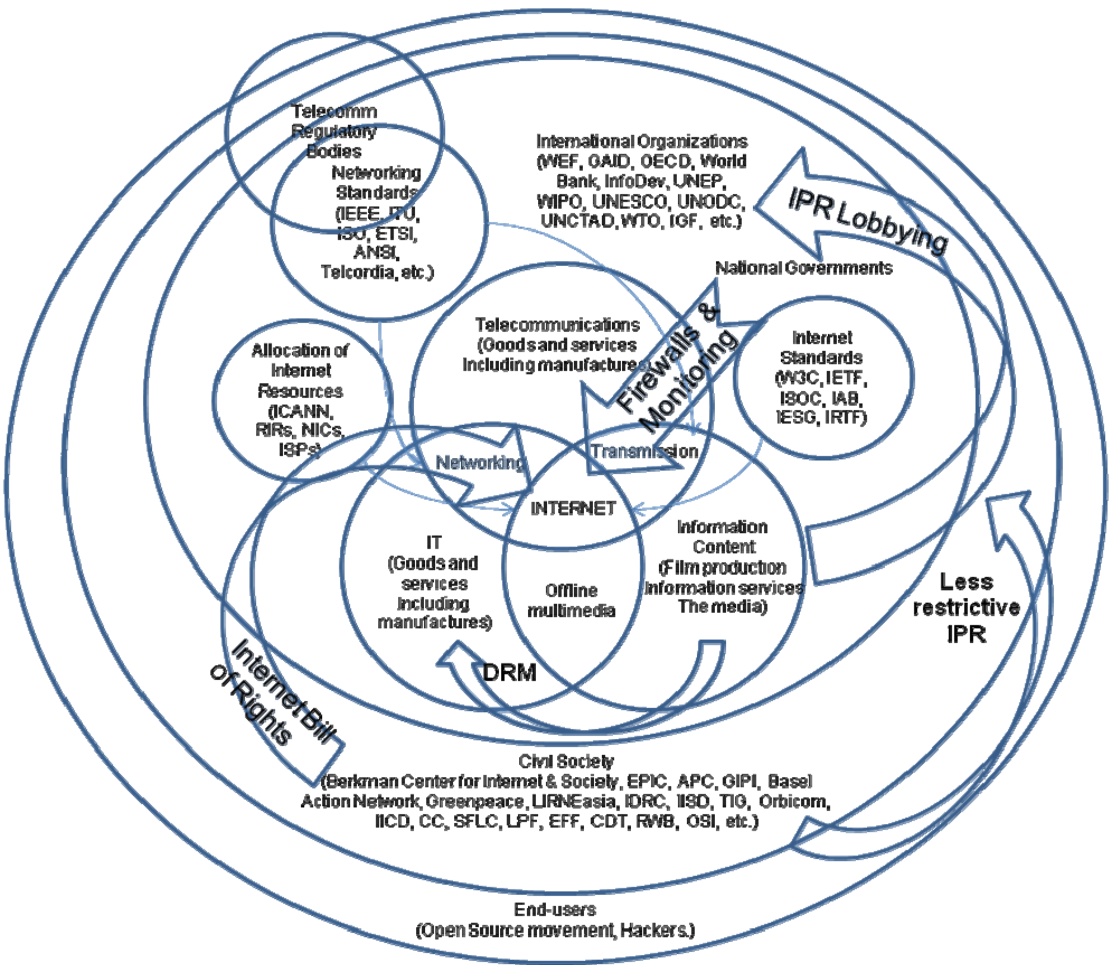

Figure 4: Dynamic tensions within the Global Connectivity System

[21] Basel Action Network (BAN) About BAN, http://ban.org/main/about_BAN.html

Many other examples of tensions attributable to the emergence of the Internet and global communications which serve to draw additional players to engage in the global connectivity system can be cited. These tensions just described, depicted in Figure 4, hopefully demonstrate that this system will only continue to extend beyond the core ICT hardware, software and service providers, to increasingly include digital content providers, governmental and international institutions involved in content as well as environmental regulations, civil society institutions involved in the protection of on line civil rights and well as the environment, down to villagers in developing countries dismantling circuit boards.

5.0 Trends Across the Global Connectivity System as an Outcome of ICT Innovation

The remainder of this paper will present data and trends specific to the influence of ICT innovation across each axis of sustainable development: economic development; environmental protection; and social development. The global connectivity system and governance will be treated in a later paper, as IISD continues to explore these linkages.

In terms of economic development, available data point to the steady stream of ICT innovation as being the undisputed engine of modern economic growth, through new efficiencies gained with ICT adoption across other sectors. But the institutions and norms of the system that are responsible for driving the evolution and diffusion of ICT innovation unfortunately present a growing environmental challenge to achieving sustainable development. The computer and the Internet did not become transformative until their utility, performance and price reached a tipping point after which it became increasingly feasible to invent and produce new products, processes and business models.[22] This unfortunately has put into motion a feedback loop between consumers and producers. Consumers, corporations and individuals alike, are impelled to purchase the latest ICT hardware innovations to boost the utility of their ICT applications, and conversely to purchase increasingly complex ICT applications to realize the potential of their hardware investments. This has resulted in an "arms race" between ICT hardware and application producers as they race to capitalize on the new market opportunities they enable for each other. The unfortunate by-product of this feedback loop is rapid obsolescence of ICT hardware, the disposal of which has created a global e-waste crisis. This paper presents alarming trends showing that consumption of ICTs not only far exceeds current efforts to re-use and responsibly recycle, but that the e-waste problem is likely to continue growing exponentially.

ICT innovation also presents new opportunities and challenges for the social development dimension of sustainable development. The right to freedom of expression is a norm at the very

[22] Atkinson, R. D. & McKay, A. (2007).

heart of the Internet's open and participatory nature and is a founding principle of many of its key institutions. Freedom of expression enables people to challenge unsustainable practices, to demand their rightful place in developing alternatives for sustainability and changing social and economic structures which negatively affect their communities.[23] It should therefore come as no surprise that the SD community has been quick to recognize the potential of the Internet for reinventing citizens' roles in the political process and changing institutions, policy-making and governance. Unfortunately, increasingly sophisticated measures for monitoring and controlling user behaviour on the Internet are far too readily employed by corporations and governments, whose agendas often run counter to traditional concepts of user rights. Many critical uncertainties on this front have the potential to significantly diminish or eliminate the utility of the Internet. It is therefore surprising that the SD community has been largely absent from efforts to mitigate these uncertainties.

Much of the progress promoting the integration of sustainable environment, human development, and economics in decision-making, made by the SD community, has been accomplished by coordinating efforts to raise awareness of unsustainable trends and practices in specific economic sectors, and proposing alternative practices and policies to support their realization within those sectors. However in the case of the ICTs, the boundaries imposed by the traditional means employed for defining the ICT sector have in the past limited our ability to conceptualize the extent of it influence beyond being simply a domain of manipulating, transmitting and deciphering "1s" and "0s." As a result a convincing case has yet to emerge for focused treatment from the SD community of the global connectivity system as a whole. Hopefully the foundation laid by this paper to describe the ICT sector in a manner that helps identify the broader parameters directing its activities, along with the trends being observed across the three pillars of sustainable development, helps identify how the entire system could be influenced, shifted or redesigned, to better contribute to a global transition to sustainability.

6.0 Economic Development and ICT Innovation

The significance that ICT innovation has had in the growth of industrialized economies has not always been obvious. When the dot-com bubble burst post-2000, many analysts concluded that the ICT economy was "smoke and mirrors."[24] This is not the first time the link between ICTs and economic growth has been so discarded. When ICTs started seeing wide use in the 1980s, many economists expected to see productivity improvements shortly thereafter. However the reality as famously captured by the economist Robert Solow was, "we see the computer age

[23] Youth Sourcebook on Sustainable Development. Winnipeg: IISD, 1995. Online. http://www.iisd.org/youth/ysbk040.htm

[24] Atkinson, R. D. & McKay, A. (2007). *Digital Prosperity. Understanding the Economic Benefits of the Information Technology Revolution*. Washington, DC: Information Technology and Innovation Foundation. Retrieved July 3, 2008 from http://www.itif.org/files/digital_prosperity.pdf

everywhere except in the productivity statistics."[25] In response to such observations, policy-makers started facilitating "complementary investments in organizational change, process re-structuring, skills development, and the creation of an enabling environment"[26] to accompany ICT implementation, and productivity gains eventually started to emerge. The preliminary benefits observed were that "from the 1970s to the 1990s productivity grew 1.1 per cent per year for sectors investing heavily in computers and approximately 0.35 per cent for sectors investing less."[27]

However ICTs back in the 1980s were still in their infancy and economy wide improvements in productivity were not to take hold until the mid-1990s when the decline of ICT prices started to accelerate, the Internet started to emerge, and network effects began stimulating rapid innovation and improvements in the utility of ICTs. It was at this point that the ICT revolution truly started, characteristic of what technology-historian Carlota Perez calls the "installation phase" when "new technologies erupt in a maturing economy and advance like a bulldozer disrupting the established fabric and articulating new industrial networks… (but where) revolution is a small fact and a big promise."[28] Perez suggests that all technological revolutions eventually come to a turning point before moving to the "deployment period" when "the fabric of the economy is rewoven and reshaped by the new technology and system and when the technology becomes normal best practice … ready to serve as a propeller of widespread growth."[29] It is at this turning point that the economy usually suffers a downturn, as was seen with the dot-com crash in 2000, where in negotiating this critical transition, business models either thrive or are destined to die. The sector's experience eight years later also seems consistent with the idea of the ICTs becoming normal best practice. ICT hardware, software, applications and telecommunications are now used extensively in all aspects of the economy, "including internal operations of organizations (business, government and non-profit); transactions between organizations; and transactions between individuals, acting both as consumers and citizens, and organizations."[30]

Throughout the ICT revolution, high expectations by businesses and consumers have prompted significant investment into the ICT sector for decades and that trend persists despite the dot-com crash. In the U.S. economy, capital from IT products has grown at double-digit rates during most of the last three decades, whereas non-IT capital has grown at about the same rate as the economy as a whole, an order of magnitude more slowly.[31] The ICT sector sees the most research and technological development investment globally at 32 per cent in 2006 to 34 per cent

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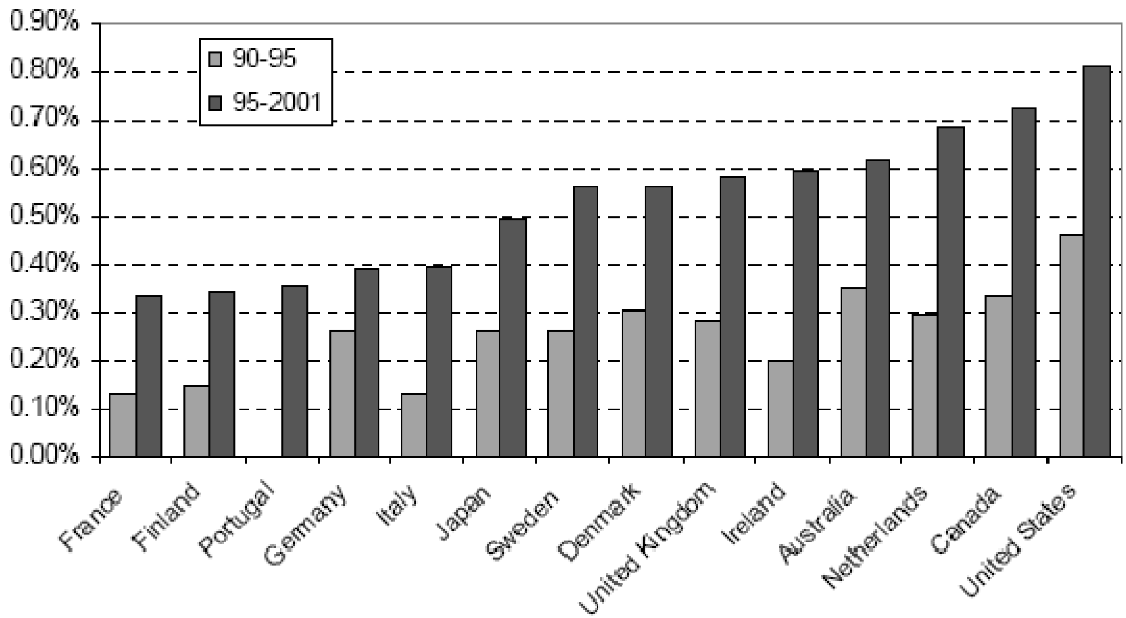
[25] Ibid.
[26] MacLean D., St. Arnaud, B. (2008) ICTs*, Innovation and the Challenge of Climate Change,* International Institute for Sustainable Development, Retrieved July 3, 2008 from http://www.iisd.org/pdf/2008/ict_innovation_climate.pdf
[27] Atkinson, R. D. & McKay, A. (2007).
[28] Ibid.
[29] Ibid.
[30] Ibid.
[31] Jorgenson, Dale (2005)

in 2007, and the European Union (EU) reports that over half of all venture capital (VC) money last year went into their ICT sector.[32] Over the last 15 years, $1.5 trillion has been invested globally in mobile communications and Internet access.[33]

The data available on the impact of all this investment on productivity and economic growth is impressive. A study by Jorgensen, Ho and Stiroh found that in the United States, ICT capital was responsible for two thirds of total factor productivity growth between 1995 and 2002, and virtually all of the labour productivity growth, with similarly significant data for other nations including developing countries.[34] The impact that ICT capital had on productivity was also found to be three to five times that of non-ICT capital. In terms of impact on economic growth, a paper authored by Ahmad, Schreyer and Wölfl for the Organisation for Economic Co-operation and Development (OECD) showed that inflation-adjusted investment in ICT accounted for an average of 0.5 percentage points of annual growth in real GDP in OECD countries between 1995 and 2001, representing an average of 20 per cent of total growth in real GDP, 25 per cent in the case of the United States, Canada, the Netherlands and Australia.[35] Figure 5 shows the increase in ICT capital contribution to GDP growth for OECD countries between 1990–1995 and 1995–2001.

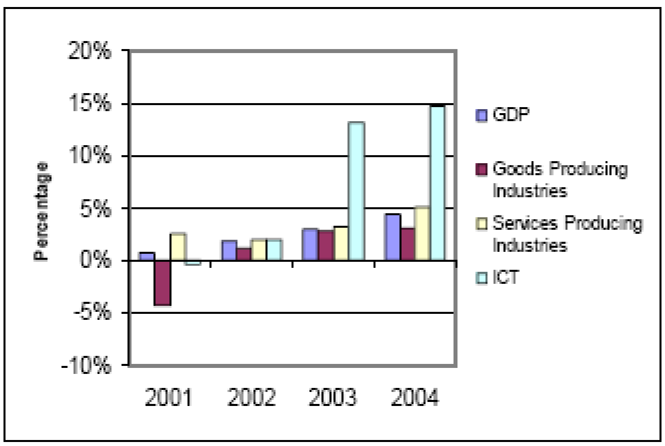


[32] Johnston, Peter (2008)
[33] Ibid.
[34] Atkinson, R. D. & McKay, A. (2007).
[35] Nadim Ahmad, Paul Schreyer and Anita Wölfl (2004), *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD. Retrieved July 3, 2008 from http://www.oecdbookshop.org/oecd/display.asp?CID=&LANG=EN&SF1=DI&ST1=5LMQCR2JFTLN

Figure 5: The contribution of growth in ICT capital assets to GDP growth, 1990-1995 and 1995-2001, in percentage points[36]

More recent data show that despite having to recover from the dot-com crash, the ICT sector contributed 16 per cent of global GDP growth from 2002 to 2007.[37] There are not a lot of data available for developing countries, however a widely cited study by Vodafone found that a developing country which had an average of 10 more mobile phones per 100 people between 1996 and 2003 had 0.59 per cent higher GDP growth than an otherwise identical country.[38] In China, improved communication is considered to have played a role in increasing wealth by driving down commodity prices, coordinating markets and improving business efficiency.[39]

The growth of the ICT sector itself has also far exceeded that of any other sector. The U.S. ICT sector increased its contribution to GDP three times faster than other sectors (see Figure 6). For example, in 2004, goods- and service-producing industries raised their real value-added by 3.1 per cent and 5.1 per cent respectively, whereas the ICT sector showed a 14.7 per cent increase.[40] In Canada, the average annual growth rate of the ICT sector has been 8 per cent since 1997, even including the dot-com crash, more than twice the 3.5 per cent average for economic growth over the same period.[41]



[36] Ibid.
[37] The Climate Group (2008). SMART 2020: Enabling the Low Carbon Economy in the Information Age. Brussels, Belgium: Global e-Sustainability Initiative. Retrieved July 3, 2008 from http://www.climatebiz.com/files/document/Smart-2020-Report.pdf
[38] Vodafone (Ed.) (2006). Africa: The Impact of Mobile Phones. London: Vodafone. http://www.vodafone.com/etc/medialib/attachments/cr_downloads.Par.78351.File.tmp/GPP_SIM_paper_3.pdf (last accessed Nov 27, 2008).
[39] Eggleston, K., Jensen, R. and Zeckhauser, R. (2001). "Information and Communication Technologies, Markets, and Economic Development" in Kirkman, G. S. (ed) The Global Information Technology Report 2001-2002. Oxford: OUP.
[40] Iansiti, Marco and Gregory L. Richards, *Information Technology Ecosystem Health and Performance*. Harvard Business School Working Paper No. 06-013 (2005).
[41] Patterson, Tony (2006). *National Capital SCAN ICT sector running too fast for people to keep up*, http://www.nationalcapitalscan.ca/news/2006/11/ict_sector_running_too_fast_fo.html (last accessed July 3, 2008).

Figure 6: Change in contribution to GDP, 2001–2004[42]

All of this data and the trends shown definitively demonstrate that the ICT sector and the innovation it drives are a major source of economic growth and that trends suggest this influence is only going to increase in the future. Given that much economic growth in general is occurring in an unsustainable manner, the SD community should derive motivation from this information alone to dedicate more of its resources to understanding whether ICT-driven growth is sustainable on balance.

6.1 ICTs and the unsustainability of economic growth: GHG emissions

The good news about ICT-driven economic growth is that there is compelling evidence this growth is accompanied with reduced energy consumption per dollar of economic output through productivity gains and net gains in cost-effective energy savings. One study has estimated that for every extra kilowatt hour of electricity that has been used to power ICTs, the U.S. economy increased its overall energy savings by a factor of 10.[43] This has been through the deployment of ICTs playing a critical role in reducing energy waste and increasing energy efficiency throughout the economy, through the use of sensors and microprocessors enabled control systems, as well as by enabling system-wide energy savings. The ICT sector itself, benefiting from its own continuous innovation, is also "significantly 'cleaner' per unit value added generated" with "CO_2 emissions and energy per unit gross value added generated"[44] comparably lower than other sectors. It is argued that this has played a major role in helping the U.S. economy to reduce its energy consumption per dollar of economic output from 18,000 BTUs in 1970 to less than 9,000 BTUs by the end of 2008.[45] The link to ICTs is inferred by data which show from 1986 to 1996 the energy intensity of the U.S. only dropped at an annual rate of 0.8 per cent. However, during 1996–2001 and 2001–2006, periods of rapid diffusion of ICTs, U.S. energy intensity dropped at annual rates of 2.9 per cent and 2.4 per cent respectively.[46] Such observations unfortunately lull many into believing that investing in the diffusion of ICTs throughout the global economy to such ends alone will eventually lead to achieving sustainable development, a welcome out for those hoping to avoid the contentious issue that behavioural change is ultimately required.

The obvious reality is that these annual reductions in energy intensity have not been large enough to reduce total energy consumed because they have been dramatically outpaced by increases in consumption. For example, the energy intensity in the EU-25 fell at an average rate of 1.2 per

[42] Ibid.
[43] Laitner, John A. "Skip" and Karen Ehrhardt-Martinez, (2008). *Information Technologies: the Power of Productivity*. American Council for an Energy-Efficient Economy. Retrieved July 3, 2008 from http://greeninnovation.com.au/downloads/Education/ACEEE%20how%20ITC%20reduces%20energy%20cost.pdf
[44] Fuchs, C. (2008). The implications of new information and communication technologies for sustainability. *Environment, Development and Sustainability*. 10:291-309.
[45] Laitner, John A. "Skip" and Karen Ehrhardt-Martinez, (2008).
[46] Ibid.

cent per year from 1990 to 2003, but total energy consumption increased by 10.9 per cent over the same period.[47] It is believed that technology improvements that facilitate better energy efficiency are partially at fault. Energy economists refer to this phenomenon as a rebound effect where "a more energy-efficient (technology) reduces manufacturing costs and, consequently the final price of a unit of product or service, which in turn increases demand."[48] This issue of ICT diffusion being a potential trigger for energy consumption rebound effects is worthy of greater attention from policy-makers and the SD community. As was mentioned in the previous section, huge investments are being made into the ICT sector with large expectations for economic growth through the efficiency improvements. More awareness of the issue of rebound effects may help lead policy-makers to influence the objectives of investments being made into the ICT sector to directly complement absolute energy consumption reduction policies as well as targeting more aggressive offsetting of rebound effects.

For example, a recent study by Gartner estimated that, as a result of its own energy consumption, the ICT sector accounts for 2 per cent of global GHG emissions, or 0.53 billion tonnes (Gt) carbon dioxide (CO_2) as of 2002.[49] This is roughly an equivalent contribution to that of the airline industry. A report commissioned by the Global e-Sustainability Initiative (GeSI) building on the Gartner study projected that the ICT sector's global GHG emissions would increase with sectoral growth at 6 per cent per year reaching 1.43 Gt CO_2 by 2020, even with assuming that ICT innovations would continue to improve on CO_2-emissions and energy use per unit gross value added.[50] The report however goes on to identify specific ICT opportunities which "could lead to emission reductions five times the size of the sector's own footprint, up to 7.8 Gt carbon dioxide equivalent (CO_2), or 15 per cent of overall business as usual (BAU) emissions by 2020." As the same time the report stresses that "prevention of the rebound effect requires an emissions-containing framework (such as emission caps linked to a global price for carbon) to encourage the transition to a low-carbon economy. Without such constraints there is no guarantee that efficiency gains will not lead to increased emissions."[51]

7.0 The Environmental Challenge of ICT Innovation

The undisputed fuel of ICT innovation has been over 40 years of exponential progress in semiconductor technology. "In 1965, Gordon Moore observed that the number of components

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[47] Johnston, Peter (2008).
[48] Plepys, Andrius (2002), *The Grey Side of ICT*, Environmental Impact Assessment Review, Vol: 22 Issue: 5, October, 2002, pp: 509‐523.
[49] Gartner Estimates ICT Industry Accounts for 2 Percent of Global CO_2 Emissions, http://www.gartner.com/it/page.jsp?id=503867 (last accessed July 3, 2008).
[50] The Climate Group. 2008. SMART 2020: Enabling the Low Carbon Economy in the Information Age. Brussels, Belgium: Global e-Sustainability Initiative. Retrieved July 3, 2008 from http://www.climatebiz.com/files/document/Smart-2020-Report.pdf
[51] Ibid.

on an integrated circuit was doubling roughly every 12 months with a commensurate reduction in cost per component. In 1970, he extended the amount of time to 24 months."[52] The three graphs shown in Figure 7 depict the effects of what has become known as Moore's Law over the last 40 years.

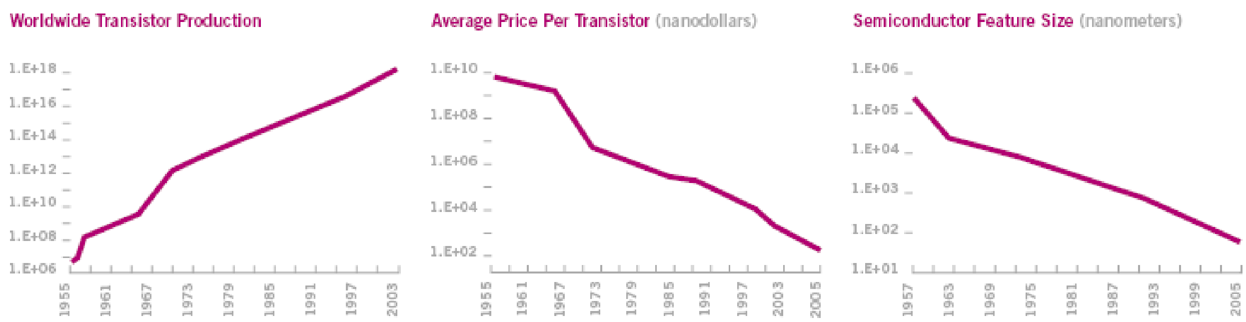

Figure 7: Moore's Law demonstrated by empirical data[53]

These graphs show continuous and simultaneous exponential increases in the number of transistors that can be placed on a semiconductor chip, exponential reductions in cost, and exponential increases in performance. These trends have driven a staggering penetration of ICT well beyond the ICT sector itself. "By one estimate, only 2 per cent of all the microprocessors and chips sold in the world today are for use in traditional servers, desktops, laptops, and mainframes."[54] It is hard to grasp what these trends really mean in comparison to other industrial activities. Here are a few anecdotes that help put it into perspective.[55]

- A $1,200 personal computer in 2005 had more processing power than the mainframe computers used by NASA to put men on the moon in 1969.
- In 1978, a commercial flight between New York and Paris cost $900 and took seven hours. If the principles of Moore's Law were applied to the airline industry, that flight would now cost about a penny and take less than one second.
- In 2005, more transistors were produced—and at a lower cost—than grains of rice.

Beyond transistor innovation, exponential trends like those predicted by Moore's Law have been realized in many other core ICT technologies including memory, processors, storage, sensors, displays and communication (see Table 1).

[52] Semiconductor Industry Association 2005 Annual Report. *2020 Is Closer Than You Think*. Retrieved July 7, 2008 from http://www.sia-online.org/downloads/SIA_AR_2005.pdf
[53] Ibid.
[54] Schwartz, Ephraim (2004). "Devices Get Smart." Infoworld, April 9. http://www.infoworld.com/article/04/04/09/15OPreality_1.html (accessed July 10, 2008).
[55] Semiconductor Industry Association 2005 Annual Report.

	years
Total bits shipped	1.1
Microprocessor Cost per Transistor Cycle	1.1
Magnetic Data Storage	1.3
Dynamic Random Access Memory (RAM) (bits per dollar)	1.5
Average Transistor Price	1.6
Processor Performance in MIPS	1.8
Transistors in Intel Microprocessors	2.0
Microprocessor Clock Speed	2.7

Table 1: ICT doubling or halving times

Here are a few data points that help to illustrate the impact these exponential innovation trends are having on ICTs.[56]

- The real price of servers fell approximately 30 per cent per year between 1996 and 2001.
- Hard drive storage capacity has doubled every 19 months while the cost of a stored megabyte of data has fallen 50 per cent per year ($5,257 in 1975; $0.17 in 1999; $0.005 in 2002; and $0.001 in 2007).

The trends predicted by Moore's Law have been sustained by continuous and ever increasing investment in the ICT sector, spurred on by recognition of the impact of ICT innovation on overall economic growth. Increasingly, the need to sustain this investment is being flagged to policy-makers as a national priority. George Scalise, President of the Semiconductor Industry Association, stated in their 2005 annual report that "our nation's economic progress, standard of living and national security depend in large measure on maintaining leadership in semiconductor

[56] Atkinson, R. D. & McKay, A. (2007).

technology."[57] In 2005, the U.S. Defence Science Board Task Force on High Performance Microchip Supply warned that the relocation of critical microelectronics manufacturing capabilities to other countries could pose significant national security and economic concerns.[58] So it is clear that there is significant investment and attention being directed towards sustaining these trends for the foreseeable future. Given the exponential nature of these trends, understanding their links to issues of sustainability should be a priority. The answer to this question lies in understanding the ICT sector and the innovation, supply and demand dynamics that sustain it.

Behind every exponential trend is a positive feedback loop. Positive feedback loops are created by "network externalities."[59] In the case of ICT innovation the externality has been the steady stream of investment directed towards the ICT sector. However it is the interplay between the price and performance of ICT HW and the utility of ICT applications that is responsible for the feedback loop itself. It is this interplay that led to ICT becoming a "general purpose technology." The hallmark of general purpose technologies is that they drive economic transformation and growth, past examples being the steam engine, railroads, electricity and the internal combustion engine. They have three characteristics: utility to most economic sectors; performance and price improvement, often dramatically, over time; and they make it easier to invent and produce new products, processes and business models.[60] ICTs did not initially possess all three of these characteristics until a tipping point was reached in their performance and price which created the conditions necessary to start the ICT innovation feedback loop, the trigger for which was a breakthrough in software design.

A prominent U.S. computer scientist Carver Mead, who is credited by Gordon Moore for coining the term "Moore's Law," took Moore's observation that transistor counts were likely to continue to double every 24 months and added that their price would likely also halve. "This, Mead realized, meant that we should start to 'waste' transistors."[61] This observation did not initially register with computer professionals who had spent their entire careers refining and optimizing computer algorithms to conserve processor capacity. However Alan Kay, an engineer working at Xerox's Palo Alto Research Center, started experimenting with the frivolous use of computer resources to generate graphics and animations solely for the purpose of making

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57 Ibid.

58 Defense Science Board, *High Performance Microchip Supply*, February 2005 http://www.acq.osd.mil/dsb/reports.htm (last accessed July 9, 2008).

59 Kelly, Kevin (1998). *New Rules for the New Economy: 10 Radical Strategies for a Connected World*, New York: Viking Penguin. http://www.kk.org/newrules/newrules-2.html (last accessed July 9, 2008).

60 Atkinson, R. D. & McKay, A. (2007).

61 Anderson, Chris (2008). "Free! Why $0_00 Is the Future of Business," WIRED Magazine: 16.03. http://www.wired.com/techbiz/it/magazine/16-03/ff_free?currentPage=all (last accessed July 9, 2008).

computers easier to use for non-techies, including children, and the graphical user interface (GUI) was born.[62] The first popular commercial application of the GUI was the Apple Macintosh which triggered an industry wide rethink of the user friendliness of software user interfaces. With this paradigm shift towards a liberal perspective on computing resources developers also realized that significant market opportunities existed in new software applications feasible in situations where previously they were not economically viable. The result was more software with broader appeal and a rapid growth in the user base, who in turn found even more uses for computers. Emerging cutting edge software applications increasingly tax currently available computing resource, which creates a demand for the next generation of HW enabled by ICT innovation tracking to Moore's Law, thus completing the feedback loop.

Given the exponential growth in computer capacity and performance tracking Moore's Law one might think that such increases would eventually outpace application innovation and demand. If this were to occur computer manufacturers would have eventually experienced a decline in product volumes and a related decline in sales revenues. To compensate they would have likely been forced to either increase their price per unit to offset the reduced volume or face going out of business. However the opposite has occurred. Volumes of computer equipment continue to grow while prices per box remain the same or fall. This outcome is analogous to the rebound effect observed in energy consumption as a result of increased energy use efficiency. In this case, the increasing efficiency of computer price and performance has resulted in a rebound effect reflected in their demand. However software innovation keeping pace with improvements in HW price and performance only partially explains this outcome. ICT products are also being retired after increasingly short periods of time. One reason is that industries in the ICT sector have realized the strategic advantage of faster product cycle times for claiming or maintaining market leadership, and as a cost-reduction strategy. This has resulted for example, in the intended lifespan of computer central processing units (CPUs) dropping from four to six years in 1997 to two years in 2005.[63] As can be expected, SW engineers optimize their applications to operate with the most performing equipment on the market however their requirements increasingly spell doom for aging machines that were still able to squeak by a year ago forcing their earlier retirement. This is especially evident in the most dynamic consumer products such as computers and mobile telephones.[64]

In terms of drivers another interesting trend has emerged which has significant implications for the pace of ICT innovation. The resulting steady diffusion of ICTs into the society at large has placed increasingly sophisticated, and at the same time user friendly tools of ICT innovation into

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62 Ibid.

63 Babu, B. R., Parande A. K. and Basha C. A. (2007). "Electrical and Electronic Waste: A Global Environmental Problem," Waste Management and Research, Vol. 25, No. 4, 307-318, 2007.

64 Plepys, Andrius (2002).

the hands of the general public. Cisco CEO John Chambers recently singled out "social networking, video sharing and wiki-enabled practices of Internet-connected consumers that facilitate collaboration and user-editing" as innovations responsible for this new trend. Chambers suggested that the increasing use of these tools has resulted in a reversal of previous trends in that, "consumers are now driving innovation that is migrating up to the enterprise, instead of enterprise innovation trickling down to consumers."[65] This trend will likely be further strengthened as users are empowered to network with an increasing number of devices in their environment and play a role in the building of the Internet of Things.

Exponential trends, by their nature, are unsustainable. It is therefore critical to examine whether exponential trends in ICT innovation are driving unsustainable outcomes. The rapid emergence of the Internet is one of the crowning achievements of the ICT sector and has arguably helped to create significant public goods. However the Internet's growth has been underpinned by very rapid consumption of new products and services. Figure 8 shows data from Netcraft's June 2008 Web Server Survey with the number of responses from hostnames topping 172,338,726 sites.

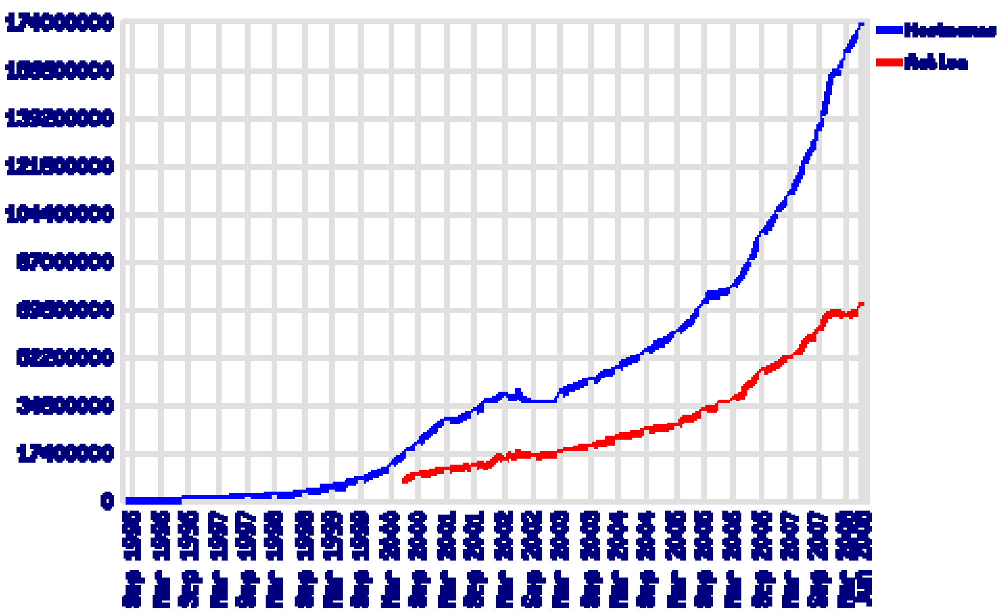

Figure 8: Total sites across all domains August 1995 – June 2008[66]

The exponential growth in Internet hostnames has been matched by an equally exponential growth in the number of Internet users as shown in Figure 9. The International Data

[65] Cisco's Chambers Telecom entering 'Phase II' - Network World, http://www.networkworld.com/news/2007/061907-cisco-chambers.html (accessed July 14, 2008).
[66] Web Server Survey Archives – Netcraft, http://news.netcraft.com/archives/web_server_survey.html (accessed July 15, 2008).

Corporation (IDC) projected that roughly 1.5 billion people will use the Internet on a regular basis in 2009.[67]

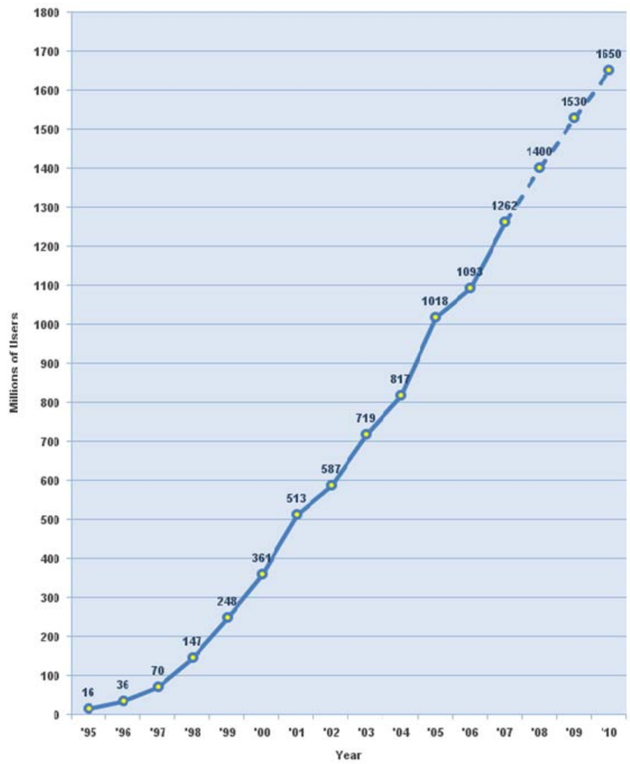

Figure 9: Growth in Internet users in the world[68]

7.1 Personal computers

According to IDC, in 2009 these users will access the Internet through more than 1.5 billion devices, including PCs, mobile phones and online videogame consoles. It is no surprise, therefore, that the number of personal computers recently surpassed one billion units, according to Gartner. Gartner analysts estimate that the worldwide installed base of PCs is growing at just under 12 per cent annually and will surpass two billion units by early 2014.[69] With the track record ICT penetration has established for driving economic growth such trends are likely good news for many emerging markets. In fact, Gartner expects "emerging markets to account for approximately 70 per cent of the next billion installed PCs."[70] However, with the average lifespan of PCs being driven shorter by rapid ICT innovation and SW incompatibility how frequently is this rapidly growing installed base being replaced? Gartner forecasts that "just over 180 million

[67] IDC Finds More of the World's Population Connecting to the Internet in New Ways and Embracing Web 2.0 Activities, 25 Jun 2008, http://www.idc.com/getdoc.jsp?containerId=prUS21303808 (accessed July 15, 2008).
[68] Internet Growth Statistics - Global Village Online, http://www.internetworldstats.com/emarketing.htm#stats (accessed July 15, 2008).
[69] Gartner Says More than 1 Billion PCs In Use Worldwide and Headed to 2 Billion Units by 2014, http://www.gartner.com/it/page.jsp?id=703807 (accessed July 15, 2008).
[70] Ibid.

PCs—approximately 16 per cent of the existing installed base—will be replaced this year." Efforts to sustainably manage end-of-life PCs have been dramatically outpaced by the replacement rate of the installed base in developed countries alone as will be graphically illustrated later in this paper. Given that emerging markets are even less equipped to handle such issues both institutionally and in terms of infrastructure, how to sustainably manage the rate of growth of the PC installed based in emerging markets should be a significant issue of concern.

7.2 The digital universe

The growth in the installed base of PCs is also being accompanied by a rapid growth in the amount of digital information being created, captured, and replicated around the world. This rapid growth of digital information is in part a by-product of many positive trends for SD such as dematerialization and the democratization of information and knowledge. For example, the multinational food giant Nestlé now receives all of its orders directly from supermarkets over the Internet. The shipping company UPS used online networks to optimize its delivery routes, saving 12 million litres of fuel in 2006 from nearly 100,000 trucks.[71] The Internet is increasingly being used to link the creativity of individuals and allow organizations to collaborate and exploit new ways of disseminating information. Public organizations are increasingly creating large amounts of publicly funded Internet content, research and information and holding digital content created by others. This is "further spurring the pace and scope of research and innovation, and encouraging new kinds of entrepreneurial activity."[72] However it is the rapid increase in content associated with "digital TV, surveillance cameras, Internet access in emerging countries, sensor-based applications, datas supporting 'cloud computing,' and social networks"[73] including video-sharing sites which is driving the majority of data growth. For example, users upload some 10 hours of video per minute alone to the video sharing site YouTube.[74] As a result of these rapidly growing sources of digital information the digital universe is expected to grow from 180 exabytes in 2006 (approximately three million times the information in all the books, ever written) to 10 times that amount by 2011 (see Figure 10).

[71] OECD (2008), "Report on the future of the Internet Economy." Retrieved July 15, 2008 from http://www.oecd.org/dataoecd/20/41/40789235.pdf.
[72] Ibid.
[73] IDC (2008), "The Diverse and Exploding Digital Universe," white paper sponsored by EMC. Retrieved July 15, 2008 from http://www.emc.com/digital_universe.
[74] OECD (2008).

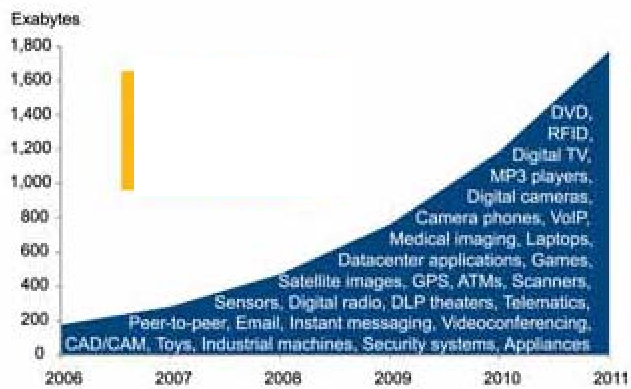

Figure 10: Digital information created, captured and replicated worldwide[75]

According to IDC, "70% of the digital universe is created by individuals, but enterprises are responsible for the security, privacy, reliability, and compliance of 85%"[76] of that universe. One of the reasons for this is the rapid decrease in the cost of storage highlighted earlier in this paper. Web companies like Google, Yahoo and Microsoft are providing consumers with large amounts of free Web-based storage for their e-mail, photos, and other files. For example, Google provides around 2.7 gigabytes of free storage for users of their Gmail e-mail service. If Google were to provide this service today using the technology of 1975 (in 2006 prices), it would cost them over $50 million per user![77] Free storage services and rapid decreases in the cost of storage encourage end-users to create even more digital information, such as higher-resolution photos and videos which in turn drives demand for more storage. Another example of a supply and demand dynamic unique to the ICT sector driven by the ICT innovation feedback loop, as well as the increasingly significant role played by end users in this ICT sector dynamic. Interestingly though, as shown in Figure 11, the amount of information created, captured or replicated exceeded available storage for the first time in 2007.

[75] IDC (2008).
[76] Ibid.
[77] Atkinson, R. D. & McKay, A. (2007).

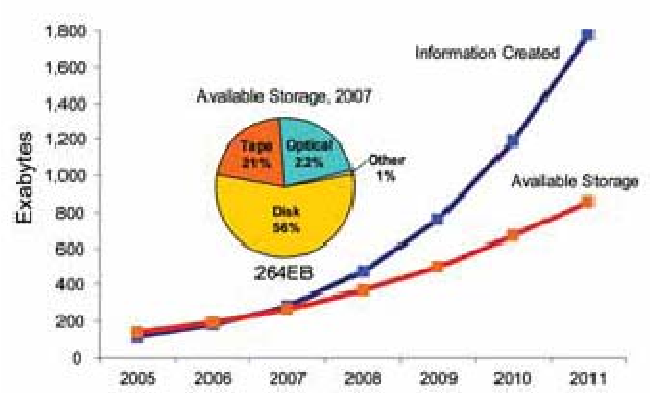

Figure 11: Information creation and available storage[78]

This is a testament to the fact that a significant portion of the digital universe is increasingly short-lived; digital broadcasts, voice calls and surveillance video. According to IDC, by 2011, almost half of the digital universe will not have a permanent home. Increasingly the digital universe is in transit over networks.

7.3 Network traffic

As confirmation, Cisco recently reported that the recent emergence of visual networking technologies such as streaming video, Web 2.0 social networking and collaboration applications, is driving unprecedented networking trends. Cisco projections indicate that IP traffic will increase at a combined annual growth rate (CAGR) of 46 per cent from 2007 to 2012, nearly doubling every two years.[79] This will amount to an annual bandwidth demand on the world's IP networks of approximately 522 exabytes (approximately equivalent to 130 billion DVDs). Here are some additional data points to help put this number into perspective.[80]

- Global IP traffic in 2002, just after the dot-com bubble, was five exabytes; the volume of IP traffic in 2012 will be 100 times as large.

[78] IDC (2008).
[79] Cisco Visual Networking Index Projects Global IP Traffic to Reach Over Half a Zettabytes in Next Four Years - News@Cisco, http://newsroom.cisco.com/dlls/2008/prod_061608b.html (accessed July 15, 2008).
[80] Ibid.

- Video on demand, IPTV, peer-to-peer (P2P) video and Internet video are forecasted to account for nearly 90 per cent of all consumer IP traffic in 2012; the Internet video traffic component alone will be 400 times the traffic carried by the U.S. Internet backbone in 2000.

These estimates are consistent with those of one of the leading experts on Internet traffic, Professor Andrew Odlyzko of the University of Minnesota, whose estimates over the past few years appear to have been correct. In his online article "Internet Growth Trends & Moore's Law," Odlyzko acknowledges the fragility of such predictions in that "there are huge potential sources of Internet traffic that already exist," Odlyzko writes, and "just a slight change in the velocity with which information circulates can have a large impact on Internet traffic."[81] However Odlyzko is optimistic that "expected improvements in standard network equipment should keep pace with traffic increases."[82] However, speaking to the role of the ICT sector elements play in influencing such trends, Odlyzko concludes that "Internet traffic growth is likely to be determined more by business models adopted by service providers (and content producers), services that are offered to users, services that users create on their own, and user acceptance of new applications. None of these can be predicted a priori, so careful monitoring of Internet traffic appears called for."[83]

7.4 Data centres

With exponential growth trends in Internet use, the digital universe, and network traffic it should be of no surprise that the facilities housing computer systems and associated components, such as telecommunications and storage systems are being stretched to their limit. One significant issue is that as Moore's-Law-driven ICT innovation is packing more processor power into ever smaller chip footprints the power density of ICT solutions has increased significantly. At the 2006 Gartner 25th Annual Data Centre Conference, Michael Bell, Gartner research vice president stated that it was then "possible to pack racks with equipment requiring 30,000 watts per rack or more in connected load … compared to only 2,000–3,000 watts per rack a few years ago."[84] Gartner predicted as a result that "by 2008, 50 per cent of current data centres will have insufficient power and cooling capacity to meet the demands of high-density equipment."[85] AFCOM, a global not-for-profit association for data centre professionals, recently predicted that "within the next five years, one out of every four data centres will experience a serious disruption

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[81] Odlyzko, Andrew (2007). MINTS–Minnesota Internet Traffic Studies. Internet Growth Trends and Moore's Law. http://www.dtc.umn.edu/mints/igrowth.html (accessed July 15, 2008).
[82] Hardesty, Larry (2008). "*Internet Gridlock - Video is clogging the Internet. How we choose to unclog it will have far-reaching implications*," Technology Review, July/August 2008, http://www.technologyreview.com/printer_friendly_article.aspx?id=20919&channel=infotech&section= (accessed July 15, 2008).
[83] Odlyzko, Andrew (2007).
[84] Gartner Says 50 Percent of Data Centers Will Have Insufficient Power and Cooling Capacity by 2008, http://www.gartner.com/it/page.jsp?id=499090 (accessed July 15, 2008).
[85] Ibid.

of their day-to-day business operation."[86] However, a flurry of innovation is under way that will converge during the next three years to substantially mitigate these issues such as virtualization, dematerialization and other efficiency measures. Virtualisation is the pooling by operating system software of assets such as computing and storage where utilisation is low, so they can be used by an application as a single logical resource. Given that average server utilization is estimated to be 6 per cent, virtualization is expected to help achieve step changes in efficiency.[87] Despite such measures a recent report commissioned by the Global e-Sustainability Initiative (GeSI) predicts that the energy needs of "data centres will grow faster than any other ICT technology, driven by the need for storage, computing and other information technology (IT) services."[88] However many ICT firms are exploring even more aggressive strategies for reducing the energy dependence of their data centres, as rising energy costs make the business cases for doing so increasingly attractive. For example, firms are increasingly turning to "cloud computing" services as an alternative to hosting their own data centre facilities. Such services support key enterprise applications via a Web browser. They can also offer on demand server space over the Web in a cost effective and energy efficient manner through virtualisation or resource consolidation. Initiatives such as the Green Grid, a global consortium dedicated to data centre efficiency and information service delivery, is working towards new operating standards and best practices, and has attracted support from the ICT sector.[89] This is another example of leadership being demonstrated by the ICT sector in the leveraging of innovations and open collaboration to achieve energy efficiencies and dematerialization of which the SD community should take note.

7.5 Mobile phones

No technology has ever spread faster around the globe than the mobile phone. Adoption rates of mobile phones have consistently exceeded analysts' predictions. This makes the trends associated with mobile phone adoption and their implications a unique target for closer sustainability examination. In 1990, there were 11 million cell phones in use in the world, compared with 519 million fixed-line phones. In 1996, the cell phone installed base increased by 53 million, overtaking the increase in fixed-line phones of 51 million. By 2002, the number of cell phone subscribers had reached 1.2 billion, outnumbering the 1.1 billion fixed-line phones. In 12 years, cell phones went from being a novelty to the most ubiquitous communications device globally.[90] Since 2002, cell phone subscriptions have continued to grow at a pace far exceeding that of any other ICT (see Figure 12).

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86 Data center experts turn to efficient energy saving technology, Creative Network Innovations, http://www.cniweb.net/media_news_11.html (accessed July 15, 2008).
87 Ibid.
88 The Climate Group. (2008).
89 Ibid.
90 Sheehan, Molly O., "Communications Networks Expand," in Vital Signs 2003, Worldwatch Institute. Retrieved July 15, 2008 from http://www.worldwatch.org/brain/media/pdf/pubs/vs/2003_networks.pdf.

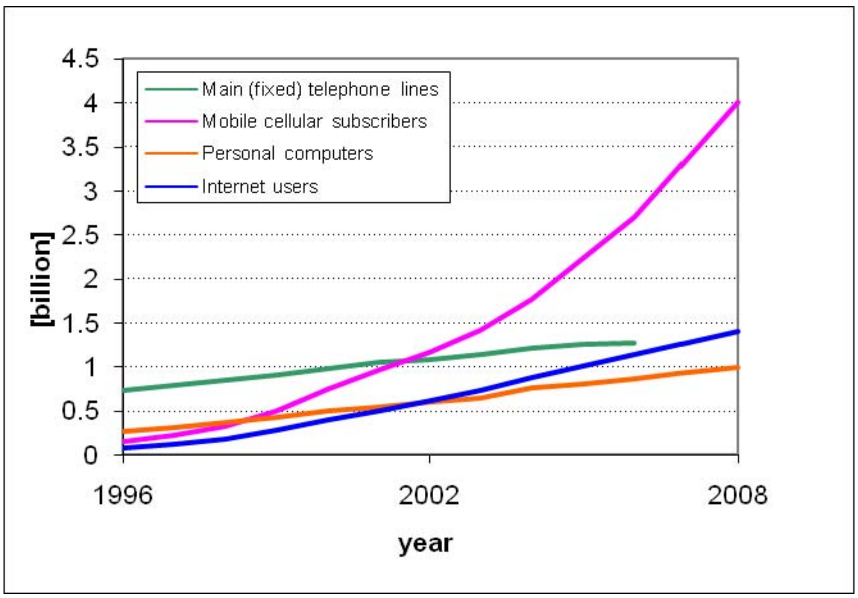

Figure 12: Key global telecom indicators[91]

One very positive outcome of the rapid penetration of mobile phones is it is paving the way for Internet access to become truly ubiquitous. The number of users accessing the Internet by mobile phone was projected to reach 546 million in 2008, nearly twice as many as in 2006, and is forecast to surpass 1.5 billion worldwide in 2012.[92] At that point in time, IDC expects the number of mobile devices accessing the Internet to surpass online PCs. Both the rapid

[91] Key Global Telecom Indicators for the World Telecommunication Service Sector, http://www.itu.int/ITU-D/ict/statistics/at_glance/KeyTelecom99.html (accessed July 16, 2008). Supplemented with data from Gartner and Yankee Group.

[92] IDC - Press Release, "IDC Finds More of the World's Population Connecting to the Internet in New Ways and Embracing Web 2.0 Activities," 25 Jun 2008, http://www.idc.com/getdoc.jsp?containerId=prUS21303808 (accessed July 16, 2008).

penetration of mobile phones and the ability many of them will have to access the Internet bodes well for helping drive economic growth in emerging markets absorbing the majority of this rapidly increasing installed base. It is expected that in 12 years time, one in two Chinese people will own a mobile phone, with a similar story in India.[93]

Another very positive outcome of the rapid penetration of mobile phones is that the populations of emerging markets are gaining access to communications infrastructure using a less resource-dependent technology. Since mobile phones rely on widely dispersed towers or on satellites for signal transmission, emerging markets need not invest in millions of miles of copper wires as the industrial countries did.[94] They are also adopting more energy efficient technologies than were originally deployed in industrialized countries. In terms of the amount of CO_2 emitted to produce, deliver and operate the network to provide a mobile service for one year, GSM subscribers have been reduced to about 25 kg, down from the first-generation networks that were about 180 kg in 1985.[95]

So why has the mobile phone market expanded so rapidly? Private sector investment and favourable enabling legal and regulatory environments have played a critical role in the rapid expansion of access to mobile networks (by 2006, 79 per cent of the global population had coverage).[96] Affordable fees and prepaid subscription plans giving flexibility & control to lower income users has also been key to expanding markets as evidenced by the percentage of subscriptions choosing this option when available (see Figure 13).

[93] The Climate Group. (2008).
[94] Brown, Lester R. (2001). Chapter 6: Designing a New Materials Economy, from Eco-Economy: Building an Economy for the Earth (W.W. Norton & Co., NY: 2001). http://www.earth-policy.org/Books/Eco/EEch6_ss6.htm (accessed July 16, 2008).
[95] Ericsson Global (2007). "Life-cycle assessment and carbon footprint," http://www.ericsson.com/ericsson/corporate_responsibility/cr07/climate_change_energy/lifecycle_assessment/index.shtml (accessed July 16, 2008).
[96] Gray, Vanessa (2008). "ICT Market Trends," a presentation to the Symposium on Telecommunications to Commemorate the 10th Anniversary of the Fourth Protocol to the GATS 20-21 February 2008, Geneva, Switzerland. Retrieved July 15, 2008 from http://www.wto.org/english/tratop_e/serv_e/telecom_e/sym_feb08_e/gray_e.pdf.

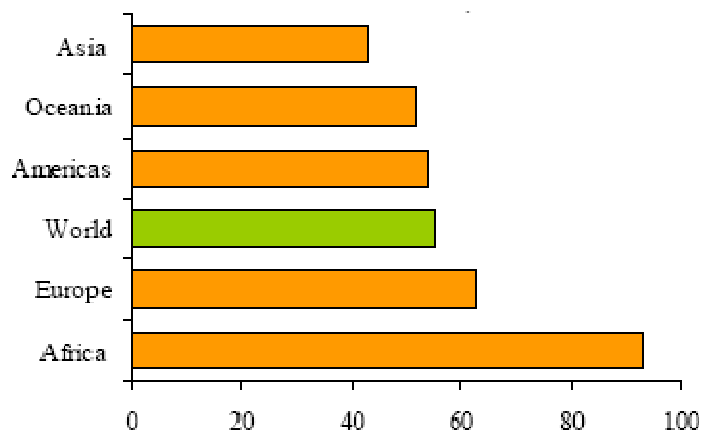

Figure 13: Prepaid subscribers as a percentage of mobile cellular subscribers, 2006[97]

ICT innovation also played a critical role in reducing the size and cost of mobile phones and increasing their functionality (affordable and easy to use SMS) delivering a range of models appropriate for diverse needs of the broad global market. However adoption rates well in excess of other ICTs is best explained by the fact that mobile phones fulfil a basic human need for security more than any other ICT to date. Mobile phones satisfy this need in many ways.

- Physical security: users can instantly contact family and friends in the event of an emergency.
- Economic security:
  - Job seekers know potential employers can always make contact.
  - Entrepreneurs can be in constant contact with revenue opportunities.
  - Eliminate market information asymmetries and ensure transactions are fair.
- Social security: facilitating social cohesion and creation of social capital.

Mobile phones foster all these forms of security more that other ICTs through their portability and constant connection to the network. One study by LIRNEasia entitled "Teleuse at the Bottom of the Pyramid" (BOP) confirms cell phones can play a role in helping to basic needs of

[97] Ibid.

the world's poor, observing that "the biggest and most widespread impact of access to telephones at the BOP is in creating a sense of security, due to the ability to act in an emergency."[98] Evidence that these needs are being met and are driving mobile phone sales also comes from surveys that have been conducted in some of the poorest countries that determined how much people are prepared to spend of their income on telecommunications.

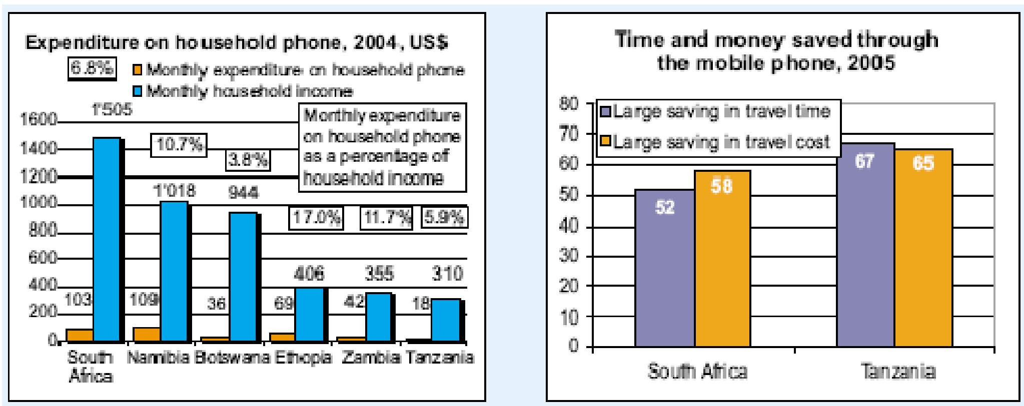

Figure 14: Why people are prepared to spend so much on a mobile phone[99]

The findings shown in Figure 14 show that people prepared to spend relatively large amounts of their revenue on telecommunications, mobile phones increasingly being their most likely option, because it helps them save money in other areas. The same study produced evidence that mobiles improve relationships with friends and family and help small businesses operate more effectively. In South Africa, 62 per cent of small businesses affirmed that they had increased their profits as a result of the mobile phone, and 85 per cent of those surveyed in Tanzania said they had more contact and better relationships with family and friends as a result of mobile phones.[100]

Objects that satisfy basic human needs so strongly often become an extension of the self and consequently there is often a desire to have it be reflective of the owner's individual identity such as it often the case with automobiles. This is particularly prevalent among the youth who are increasingly adopting ICTs as part of their identity formation and to support other critical social processes. In many industrialized countries cell phones are now considered "must-haves and young people are driving the movement to make them hipper."[101] Among the upwardly mobile

98 *Teleuse at the bottom of the pyramid: Findings from a five country study*, Background paper prepared for '3rd Global Knowledge Conference', Kuala Lumpur, 11-13 December 2007. Retrieved on July 16, 2008 from http://www.gkpcms.com/GK3/documents/07.12.12-GK3-ET8-Ayesha%20Zainudeen.doc.

99 World Telecommunication/ICT Development Report 2006: Measuring ICT for Social and Economic Development, ITU, March 2006. Retrieved on July 16, 2008 from http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-WTDR-2006-SUM-PDF-E.pdf.

100 Ibid.

101 Jameson, Tonya (2005). "*Add Bling To Your Ring*," Young Money, http://www.youngmoney.com/technology/cell_phones/050915 (accessed July 16, 2008).

cell phones are increasingly recognized as "symbols of fashion, power and usefulness."[102] Such human factors, in combination with the rapid introduction of new capabilities and features as a result of ICT innovation have resulted in rapid mobile phone replacement rates as people lay claim to the latest releases and designs; 18 months on average in the EU[103] and 12 months on average in the U.S.[104] and Japan.[105] The consequence, according to ABI Research, 60 per cent of the 1.2 billion phones were sold worldwide in 2007 probably replaced existing ones.[106] A factor aggravating these rapid replacement rates are rapid decreases in the cost of manufacturing mobile phones. Given that potential service revenues are appreciably higher, service providers in some countries subsidize the price of mobile phones by offering them for free or at a significantly reduced price in exchange for signing a contract, switching carriers or extending a contract, making the decision to upgrade to a new phone very easy to make.

Given the increasingly global installed base of mobile phone technology, the observed replacement rates pose obvious risks to sustainable development in terms of the hazardous waste associated with their manufacture and disposal. The risk also exists that these replacement rates could rapidly increase. One trigger for such an outcome could be a design paradigm shift that enables new functionality that further addresses basic human needs, or makes existing functionality significantly more user friendly. For example one of the primary drivers for interest in Apple's new iPhones is their GUI for accessing the Internet. After it initial release Google observed "50 times more search requests coming from Apple iPhones than any other mobile handset. They were so shocked, in fact, that they suspected that they had made an error tabulating their data."[107] If other mobile phone designs are able to achieve similar improvements in their GUI design the general desirability of such a feature could prompt a significant increase in mobile phone turn-over. All of these examples serve as another illustration of the significant role end users play in the innovation, supply and demand ICT sector dynamic, and how that can be unpredictably amplified when ICT applications fulfill basic human needs.

7.6 The dark side of ICT supply and demand: E-waste

Several examples of how ICT innovation has resulted in positive dematerialization outcomes have already been mentioned in this paper. In considering the role that ICTs play in the issue of

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102 "Cell phones grow as symbols of fashion, power and usefulness," Cell Phone and Wireless Service Plan Buying Guide, http://www.wirelessguide.org/cell-phone-news/fashion.htm (accessed July 16, 2008).
103 Fuchs C. (2008).
104 Mooallem, Jon (2008). "The Afterlife of Cellphones," New York Times, Wednesday, July 16, 2008, http://query.nytimes.com/gst/fullpage.html?res=980DE1DD1F3CF930A25752C0A96E9C8B63 (accessed July 16, 2008).
105 The Economist (2008). "Dropped call - Why Japan lost the mobile-phone wars," Mar 7th 2008, http://www.economist.com/daily/columns/techview/displaystory.cfm?story_id=10830025&fsrc=nwl (accessed July 16, 2008).
106 Mooallem, Jon (2008).
107 "Google; AT&T shocked by iPhone usage," The Apple Core - ZDNet_com, http://blogs.zdnet.com/Apple/?p=1316&tag=nl.e539 (accessed July 16, 2008).

waste generation it is also important to acknowledge how waste has been reduced by ICTs. For example, consider the amount of chemical pollution from the processing of film that has not been released into the environment as a result of the emergence of digital cameras. Web sites that facilitate the online buying and selling of second hand goods have also significantly increased the circulation of goods for re-use. More generally, the biggest gains in dematerialization arising from ICT innovation are expected from supply chain management, production process management,and the virtualization of goods. Unfortunately what has been observed is that "technological advances and economic restructuring have contributed to significant decoupling between rates of economic growth and material throughput but they have not achieved any overall reduction in resource use or waste volumes."[108]

In fact, to the contrary, electrical and electronic equipment waste is one of the fastest growing sources of waste. The UN estimates that some 20 to 50 million tonnes of e-waste are generated worldwide each year. If such a huge figure is hard to imagine, think of it like this—if the estimated amount of e-waste generated every year would be put into containers on a train it would go once round the world![109] European studies suggest that e-waste is increasing almost three times faster than the total waste stream, accounting for 8 per cent of all municipal waste.[110] As the exponential growth trends in ICT penetration presented earlier demonstrate, the global market for electronics is far from saturated. Combine these trends with the ever shortening lifespan of ICTs, mobile phones and computers in particular, and the result is the accelerating disposal of obsolete equipment. According to the U.S. Environmental Protection Agency, an estimated 30 to 40 million PCs will be ready for "end-of-life management" in each of the next few years.[111] Further compounding the e-waste problem is a switchover to digital high-definition television broadcasts that is scheduled to be complete by 2009 which will render inoperable TVs that function perfectly today but receive only an analog signal. In preparation for this switch about 25 million TVs have been recently been retired yearly. The concern with e-waste is that it contains many toxic ingredients such as lead, mercury, arsenic, cadmium, selenium and hexavalent chromium.[112] The processing, recycling, or disposing of e-waste therefore poses a threat to the environment and human health. For example, in a study released in 2007, 34 recent-model cell phones were put through a standard EPA test, simulating conditions inside a landfill. All of them leached hazardous amounts of lead 17 times the federal hazardous waste threshold on average, and four other metals above California hazardous levels.

[108] World Resource Institute (WRI) (2000) The Weight of Nations. Material Outflows from Industrial Economies. Developing Environmental Indicators. Washington, DC. WRI.
[109] "The e-waste problem," Greenpeace International (accessed July 16, 2008).
[110] "eBay - Give us your tired computers," Economist.com, Jan 27th 2005, http://www.economist.com/business/displaystory.cfm?story_id=3600050 (accessed July 16, 2008).
[111] "High-Tech Trash," National Geographic Magazine, http://ngm.nationalgeographic.com/2008/01/high-tech-trash/carroll-text/2 (accessed July 16, 2008).
[112] Babu, B. R., Parande, A. K. and Basha, C. A. (2007).

To date the development and introduction of appropriate re-use, recycling and recovery technologies has not been keeping pace with the growth of e-waste. In the United States, it is estimated that more than 70 per cent of discarded computers and monitors, and well over 80 per cent of TVs, eventually end up in landfills, despite a growing number of state laws that prohibit dumping of e-waste.[113] The remaining balance of discarded equipment makes its way to recyclers which is highly desirable in principle because metals such as gold and copper can be recovered for re-use. For example, a recovered cell phone circuit board can yield about a dollar's worth of precious metals, mostly gold. The environmental non-profit organization Earthworks arrived at an extremely conservative estimate that mining the gold needed for the circuit board of a single mobile phone generates 220 pounds of waste.[114] Unfortunately, companies in this business estimate that they received only 1 per cent of all phones that were discarded globally in 2006[115] in comparison to up to 30 per cent of computer equipment. If the ICT sector were to see the successful implementation of aggressive recycling programs they could also claim to have helped save possibly significant ecosystems from damage caused by the disposal of mining waste. Unfortunately, significant volumes of unused electronic gear never make it out of storage amounting, as of 2005, to about 180 million TVs, desktop PCs and other components, according to the EPA.[116] Encouraging the diversion of electronic gear currently in storage and improving rates of recycling is a significant task that requires long-term commitments from all parties that are part of the ICT sector, including consumers at the very least. Such a project is something that the SD community could potentially help the ICT sector accomplish, particularly given the mining damage that could be avoided in the process.

Seeing through proper recycling is a challenge as well. In its 2002 report "Exporting Harm" the Seattle-based Basel Action Network (BAN) revealed that about 80 per cent of electronic waste brought to recyclers in the U.S. is in fact not recycled within its borders but exported to Asia, most likely China,[117] but also Nigeria or Ghana. The precise quantities of e-waste imported into China alone are uncertain:

> The Basel Action Network estimates that 70 per cent of the 20 to 50 million tonnes produced globally end up in China (e.g., 14 million to 35 million tonnes annually). Greenpeace estimates that the total e-waste imports going to China increased from just under a million tonnes in 1990 to 17.5 million tonnes in 2000…Tshingua University, drawing from data from the Beijing Zhongse Institute of Secondary Metals estimates total illegal imports of e-waste to be around 1.5 million tonnes per annum…

[113] National Geographic Magazine (2008).
[114] Mooallem, Jon (2008).
[115] Ibid.
[116] National Geographic Magazine (2008).
[117] Technology News (2008). "A Recycled Laptop's Journey, Part 1 Exporting Toxic Waste," 01/03/08, http://www.technewsworld.com/story/hardware/61023.html (accessed July 17, 2008).

Regardless of the actual amounts of imported e-waste coming into China from foreign markets, two conclusions remain undisputed:

1. That illegal e-waste imports account for a major part of, if not the majority of, Chinese e-waste being treated in the major dismantling centres found along the Pearl and Yangtze river deltas.
2. That these illegal wastes are a major source of highly toxic chemicals giving rise to dangerous living and working conditions in the Chinese dismantling districts.

Source: Martin Eugster, Duan Huabo, Li Jinhui, Oshani Perera, Jason Potts, Wanhua Yang. A commodity chain sustainability analysis of key Chinese EEE product chains Sustainable Electronics and Electrical Equipment for China and the World. IISD, 2008.

Many recyclers simply find it easier, and that there is an attractive enough business case, to sell it to brokers who ship it to the developing world. Once there, "it is melted down in primitive, environmentally damaging conditions including the cooking and melting of computer circuit boards in vast quantity."[118] It should be of significant concern to the SD community that in areas partaking in this primitive e-waste recovery, more than 80 per cent of children have high levels of lead poisoning from burning toxic brominated flame retardants. The 1989 Basel Convention, ratified by 170 countries, and amended in 1995, was drafted to prevent these very outcomes. Once it takes effect, it will forbid hazardous waste shipments from being made to poor countries. The EU has already written its compliance into law; however the most flagrant exporter of e-waste, the U.S., is the only developed nation that has failed to ratify the Convention. The U.S. government also continues to ignore a 1986 OECD binding agreement requiring prior notification and permission from recipient countries before exporting hazardous wastes.[119] Although a few states have stepped in with their own laws, "the U.S. approach, says Matthew Hale, EPA solid waste program director, is instead to encourage responsible recycling by working with industry—for instance, with a ratings system that rewards environmentally sound products with a seal of approval."[120] In this regard the ICT sector is greening itself significantly. E-waste take-back programs are starting to be implemented by the sector in the developing world. The ICT sector has also been very responsive to the RoHS directive enacted by the EU, which stands for, "the restriction of the use of certain hazardous substances in electrical and electronic equipment."[121] This has resulted in electronics manufacturers putting programs in place to drastically lower concentrations of hazardous substances, including lead, in their products. Such initiatives are incredibly important however much more needs to be done to stem the e-waste

118 Ibid.
119 "U.S. Government OK's Illegal Trafficking in Hazardous Electronic Waste," BAN press release, 23 June 2008, http://www.ban.org/ban_news/2008/080623_us_gov_oks_illegal_trafficking_in%20electronic_waste.html (accessed July 17, 2008).
120 National Geographic Magazine (2008).
121 RoHS, http://www.rohs.gov.uk/ (accessed July 17, 2008).

tide currently lingering in second-hand markets and storage. The SD community has experience it can lend to the ICT sector that could make a significant difference in helping to stem this tide.

8.0 Social Organization and ICT Innovation

Prior to the Internet, the activity of social organization had higher transaction costs associated with it. Making contact with people not in within reasonable travelling distances involved long distance telephone fees, time-consuming letter writing and costly travel. Sharing information with other people to catalyze social organization around specific issues involved either engaging with the media sector and influencing their content or taking on the cost of copying or producing, and distributing content. In some cases content that could prove useful for rallying around a particular issue could also be subject to copyright controls making for an additional cost factor. In some countries these activities could be regulated by governments or controlled by private sector interests to such an extent that promoting social organization in general, or around certain specific issues, could exact even greater costs or represent a threat to personal security. Mechanisms for this might have included: restrictions on freedom of association, movement and expression; restrictions leaving and entering sovereign countries; monitoring; censorship; corruption; and corporate content control, to name a few.

The emergence of the Internet and other emerging ICTs such as text messaging have significantly lowered transaction costs associated with the activity of social organization and the sharing of information. The Internet in particular has also made it possible to bypass many prior controls over such activity imposed by repressive government or legal controls over the sharing of content protecting private sector interests. The reasons as to why the Internet has had this impact are linked to the principles by which it was started.

As mentioned earlier in the section describing the Global Connectivity System, the Internet's formation was based on norms intent on ensuring—through the promotion of open standards free of patent protection, and principles that placed much of the control of Internet functionality in the hands of the end-user—that anyone who wanted to help build the Internet was free to do so. The protocols (how devices communicate with each other) and the routing software (used to determine what data goes where) used for directing data over the Internet from point A to point B were designed and evolved in a collaborative and multi-organizational manner by the technical community as open standards (not patented). Also, an architecture principle promoted for the Internet advocated for as little centralized coordination as possible, meaning applications running over the Internet (e-mail, data exchanges, "surfing," streaming audio or video, etc.) could be controlled from at the end points, including the protocol[122] for allowing devices to be added to the Internet. Servers (computers acting as gateways to the Internet) and routers on the edge of

[122] Dynamic Host Configuration Protocol (DHCP)

the network that assign IP addresses to computers connecting to the Internet are the only devices to have a record of what computers are specifically attached to the Internet—end-users were anonymous to the rest of the network. The IP address of the computer used is usually logged along with also the host name (logical name). Such numbers are also logged by ISPs (Internet service provider) however it is only possible to find out who used a certain IP number at a certain time, provided that the ISP assists in the identification.

As a result of these principles, the Internet began as a space of freedom. Once people started realizing what they could do over the Internet, networks were being added at exponential rates. The growth of the Internet was managed by the technical community in much the same way that it was started—a collaborative and multi-organizational manner with little "authority" and virtually no government involvement. The growing Internet rapidly crossed sovereign boundaries with little attention from governments. The end result was the rapid emergence of a global information and communication network spanning scores of sovereign territories with effectively no governmental control over its overall operation.

One of the end results of this emergence of the Internet is the dramatic lowering of transaction costs associated with social organization. People can connect with each other from anywhere around the world independent of distance for the cost of local access to the Internet. People can also share information with each other directly over the Internet, bypassing any content controls of the media sector, at little or no cost, and—although illegal—digitize and share copyrighted material, in some cases justified by the perpetrator's belief that they should be a part of the public commons and are unjustly protected by copyright law. The anonymity of accessing the Internet also reduced the cost of potential reprisal for their action on the Internet. Private corporations that may have exercised control over media content through their ownership of media conglomerates are also powerless to suppress criticism on the Internet of their business interests or of political views counter to their own. In jurisdictions where the government has a track record for placing restrictions on freedoms, citizen can freely connect with each other over the Internet and express their ideas, unless the government is actively monitoring or firewalling Internet activity.

Even in cases where the government is monitoring the Internet strategies exist for communicating and sharing information with people outside of the country unnoticed. For example in China, savvy Internet users have known for a long time that the "great firewall" can block specific Web sites, however via Real Simple Syndication, or RSS feeds, many Chinese surfers have been free to access otherwise forbidden information.[123] Even when the Chinese government recently started blocking RSS feeds, Web-based feed aggregators, such as

[123] China's Great Firewall turns its attention to RSS feeds, http://arstechnica.com/news.ars/post/20071004-chinas-great-firewall-turns-its-attention-to-rss-feeds.html

NewsGator Online, provide a work around if the aggregator is set to display the full post (or however much of the post is made available) and the user clicks through to read more. Other workarounds abound: it is possible to establish SSH connections to servers outside the country, such as the U.S., in order to have unrestricted access to RSS and the Web; proxy tools such as the popular Firefox extension "gladder" are effective for avoiding government controls; another tool called Tor allows a client computer to access the Internet anonymously through a network of virtual tunnels—like a series of tubes, this allows users to eventually gain access to the Internet through a Tor node that is located outside of their country.

Cell phone text messaging has also had a huge impact on lowering the transaction costs associated with social organization. Sending a text message is much less costly than making a cell phone call. It is also possible for non-subscribers to send messages to a subscriber's phone using e-mail as many cell phone service providers offer the ability to do this through their Web site's mail server. Given we are approaching four billion cell phone subscriptions by the end of 2008,[124] and we are only at one billion Internet users, text messaging has greater reach as a social organization tool than the Internet, particularly in developing countries. Combined with the ability to send a text message to cell phones using the Internet, text messaging is the "last mile" Internet communications technology for more than half the world's population. Examples abound of its use for this purpose, for example Greenpeace Argentina has used mobile phones multiple times to mobilize its now 350,000 person-strong mobile list to successfully lobby for important environmental legislation.[125] One of Greenpeace's significant accomplishments was the passage of the Ley de Bosques, or Forest Law, in Argentina.

[124] Mobile phone subscriptions to reach 4 billion by year-end ITU, http://www.breitbart.com/article.php?id=080926190444.ou6iyth5&show_article=1&lst=1
[125] Global Voices Online » Mobile Phone Technology for Environmental Activism, http://globalvoicesonline.org/2008/06/05/mobile-phone-technology-for-environmental-activism/.

As this example demonstrates, the capability to self-organize is a vital tool for people to challenge unsustainable practices, to demand their rightful place in developing alternatives for sustainability, and to change social and economic structures which negatively affect their communities.[126] By dramatically lowering the transaction costs associated with social organization the Internet and other communications technologies like text messaging have become invaluable tools for sustainable development. Unfortunately the utility of these low-cost tools for sharing information and communicating with other people around the globe are under threat on a number of fronts.

8.1 Critical uncertainties that will affect social organization and development

There are a number of critical uncertainties surrounding the evolution of the global connectivity system as a

> The content and services "layer" of the Internet is the one with which most users interact, most of the time. Recent debates related to this policy arena include those related to "network neutrality" [the principle that prevents any centralized body from "shaping" traffic and so deciding who gets what content, when they get it, or how they get it] and to the role for intellectual property rights in the digital environment. The question of the role of users as creators of content and services, and as active designers of their Internet devices has recently gained some attention. A less publicized dilemma facing Internet policy-makers concerns choosing appropriate regulation philosophies from among those that governed previous mass and point-to-point communications technologies and services.
>
> Uncertainties related to Internet infrastructure include those surrounding interconnection charges, universal broadband service and major adjustments to the code, or logical, layer of the Internet: one such adjustment is the ongoing transition from one version of Internet Protocol (IPv4) to the next (IPv6). These infrastructure issues are of critical importance to the ability of remote regions and developing countries not only to get online, but to stay online in the future.
>
> Questions surrounding Internet governance processes have focused on ICANN, the Internet Corporation for Names and Numbers. The description of the organization and its operations should be evaluated against the principle of multistakeholderism on which the future of effective Internet regulation relies. In addition to the work of ICANN, the role of users in Internet governance and the sustainability of volunteer efforts in the Internet Engineering Task Force must be considered.
>
> Security is one of the most influential driving forces for the future of the Internet; indeed, with its transnational nature and unusual openness, the Internet can be seen as particularly risky to personal, economic and national security. Many subtopics fall under this broad heading, from creating user trust, to identifying and authenticating people and devices, to corporate or state-based firewalling, to the development national Internet security agendas. Recent trends toward cloud computing (where computational functions are delegated to remote servers on the "grid" and not to the local machine through which the user is accessing the network) make security concerns even more important.[1]
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> Source: Maja Andjelkovic. Critical uncertainties affecting the governance, development and deployment of the Internet. IISD, 2008.

[126] Youth Sourcebook on Sustainable Development. Winnipeg: IISD, 1995. Online. http://www.iisd.org/youth/ysbk040.htm

whole which could fundamentally alter the nature of global communications and peoples' abilities to share knowledge and collaborate. These uncertainties can be grouped into baskets of issues around content and services, infrastructure, decision-making processes and security.

In this paper, we highlight three that touch on the intersection between technology innovation and economic development and the rights and interests of users of the system.

1. Major corporations that financed and built the backbone networks of the Internet are weary of the increasing number of business models making significant amounts of money from increasingly large volumes of data being exchanged over their networks. Many of these major corporations have openly declared their intensions to increase their revenue potential by selling preferential treatment to data flows over their networks citing the cost of maintaining and growing their infrastructure as their rational. This would essentially hand control of the most accessible content on the Internet over to the highest bidders, as all other data flows would be relegated to the slow lane. Disputes between major corporations over peering arrangements between their large network backbones have also resulted in end-users discovering that they can send e-mail to some people but not to other people. Certain Web sites were suddenly dark to some users but not to others.[127]
2. Manufacturers of user devices for accessing the Internet are pursuing greater revenue potentials through their designs which place functionality under the control of the manufacture, rather than the open platform of generic computers. These "tethered" devices, such as smart phones (Blackberries, iPhones, etc.) largely close off amateur tweaking and modification placing the development and sale of new functionality under the control of the manufacturer. This is effectively stifling the very innovation that enabled them to be created in the first place. The architecture of such devices could also make it easier for some regimes to control their use and harder for end-users to work around such controls.
3. Providers of services on the Internet are increasingly gathering information on the activities of users online. This information is being used to fuel new business models that seek to leverage knowledge of users' online activities for targeted marketing campaigns and to direct users to Web content believed to be consistent with their online behaviour patterns. Some companies have even gone as far as to undertake a campaign to stifle Internet privacy legislation.128

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[127] Fragility of the networked world – MarketWatch, http://www.marketwatch.com/news/story/fragility-networked-world/story.aspx?guid=%7B93CD2015-0F80-4722-A120-D43333355B02%7D

[128] APC - ICT Policy Handbook, http://rights.apc.org/handbook/ICT_01_b.shtml. "According to the Wall Street Journal, a group of companies and industry organisations undertook a campaign to stifle Internet- privacy legislation. Led by the Online Privacy Alliance (http://www.privacyalliance.org/) in Washington, the loosely organised campaign attacked legislative proposals on three fronts: identifying expensive regulatory burdens, raising questions about how any U.S. Internet law would apply to non-Internet industries, and assuring lawmakers that privacy is best guarded by new technology, not new laws. Members of the Online Privacy Allianceinclude Microsoft Corp (MSFT), AOL Time Warner Inc, (AOL), International Business Machines Corp (IBM), AT&T Corp (T), BellSouth Corp

4. The tracking of end-user online activities is a particularly disturbing trend when married with the pressure that content producers are placing on legislators to force ISPs and services hosting depositories for content like YouTube to police the flow and use of copyrighted content. ISPs and services like YouTube have been fighting an increasing number of cases in the courts trying to protect their customers' right to anonymity. Such end-user information, if divulged, could be used to trace several years of an end-users activities on the Internet, a move many civil libertarians view as a serious threat to personal privacy.

   Anonymity on the Internet however also has a dark side. Cybercriminality has become a multi-million dollar industry that takes advantage of the borderless nature of the Internet. Cybercriminals develop malicious software or "Malware" to infiltrate or damage computer systems and to steal identities and confidential data such as credit card details. They use networks of several hundred thousands of malware-"infected" computer systems to extort money from public and private organizations by threatening to overload their services and make them unavailable. "Internet criminals" can be on another continent, and frequently route through several third-party countries, making their precise location difficult to determine and creating challenges for law enforcement which is essentially based on the idea that the criminal is physically present at the scene of the crime.

Given the threat that these, and other, critical uncertainties pose to the utility of global communications as a tool for social organization and economic development, especially in remote and developing regions, one would expect the SD community to be on the front lines of many of these issues. But surprisingly, the SD community has been absent from the debate.

9.0 Conclusion

The influence of the ICT sector on industrialized economies has been responsible for more growth over the last 15 years than any other sector. Much of this growth has been enabled by significant improvements in efficiency and labour productivity through ICT innovation. However, overall energy and material consumption continues to escalate and this paper has reiterated the case that efficiency improvements such as those facilitated by ICT innovation are a key factor in such unsustainable trends. One of the reasons the ICT sector has come to so significantly underpin the global economy is it uniquely feeds back on the supply and demand dynamic inherent within the sector itself. Along with exacerbating negative outcomes arising from consumption overall, consumption of ICTs is accelerating at rates that far exceed efforts to

(BLS), Sun Microsystems Inc (SUNW), the Motion Picture Association of America and the United States Chamber of Commerce.)"

ramp up recycling, and re-use. On the other hand, ICT innovation is providing indispensible tools for monitoring, lifecycle analysis, raising awareness of unsustainable practices, and empowering organizations and individuals to promote behavioural change necessary for achieving sustainable development.

Much of the progress made by the SD community in promoting the integration of sustainable environment, human development and economics in decision-making has been accomplished by coordinating efforts to raise awareness of unsustainable trends and practices in specific economic sectors, and proposing alternative practices and policies to support their realization within those sectors. Notable targets have been the sectors of agriculture; construction; energy; mining and metals; transportation; water; and forest products. However the ICT sector, which has been the leading engine of growth for today's global economy, has received a more bifurcated approach through the separate lens of ICT4D and the environmental opportunities and challenges of wide-scale ICT diffusion. This paper has argued that this is due to the challenge of indentifying the ICT sector in a manner that meaningfully accounts for all of the actors and activities responsible for its scope and influence. Hopefully the foundation laid by this paper will contribute to a more systematic process of identifying how the sector could be influenced, shifted or redesigned to better contribute to a global transition to sustainability.