MSc Program
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The role of ICT in sustainable development: an analytical timeline of energy consumption trends

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, Austria on June 10, 2010

Affidavit

I, **Tyler Ashton**, hereby declare

1. that I am the sole author of the present Master's Thesis, "The role of ICT in sustainable development: an analytical timeline of energy consumption trends", 65 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 10.06.2010

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Signature

Preface and Acknowledgements

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Abbreviations

AC	–	Alternating Current
BAU	–	Business As Usual
CPU	–	Central Processing Unit (of computer)
DC	–	Direct Current
EPA	–	(United States) Environmental Protection Agency
EPEAT	–	Electronic Product Environmental Assessment Tool
GWh	–	Gigawatt hours
HVAC	–	Heating Ventilation and Air Conditioning
ICT	–	Information and Communication Technology
ITU	–	International Telecommunications Union
kWh	–	Kilowatt hours
LAN	–	Local Area Network
PC	–	Personal Computer
ppm	–	parts per million (measure of concentration)
R&D	–	Research and Development
RoHS	–	Restriction on the use of certain Hazardous Substances
UPS	–	Uninterruptible Power Supply
WAN	–	Wide Area Network
WEEE	–	Waste Electrical and Electronic Equipment

Abstract

This work will examine the historical development of the energy demand of Information and Communication Technologies (ICT) within the last three decades (from 1980 until 2010) and project future development until 2020. Research will focus on what energy usage of in the ICT sector itself is and how it impacts global energy consumption. Regulation related to energy usage in the industry will be examined along with the possibilities for the mitigation or reversal of the effects caused by the boom in demand for ICT as well as the role that ICT can play in reducing energy demand in other sectors.

Information relevant to energy usage and ICT will be surveyed and summarized in the work. The objective of this work will be to synthesize and analyze, in a comparative and analytical as well as quantitative and qualitative fashion, and recommendations for the more intelligent usage of ICT in the future will be made.

The role of (and energy demand of) ICT has increased as a percent of the total share of energy consumption and until recently ICT was not viewed as a significant factor in overall energy and resource consumption. But now that sustainable development has moved into the limelight in the public as well as private sector, ICT has been viewed in a different light – namely that of how it can be used to increase efficiency in other sectors. But relying on ICT to solve the problem is not prudent – recent phenomena associated with ICT such as the rebound effect and the enabling effect must also taken into account and what role they can play in sustainable development determined.

The prevalence of ICT and thus the energy usage connected with its use, production, and disposal will continue to increase until 2020, and in the following decades. However the increase in the sheer number of ICT devices will also help contribute to an overall reduction in energy usage. This reduction will be effected by increased availability of information related to energy usage which can be provided by the employment of ICT in applications such as smart electrical metering and increases in efficiency of the power grid due by usage of ICT.

Chapter I

Introduction

There is no lack of information in the field of so called "Green IT", both in the academic world and in the business world, as one look in any search engine on the Internet or a quick glimpse into the report database of one of the major consulting firms will show. This thesis will look at the field of sustainable IT using an inter-disciplinary approach. Information – drawing from the political sphere, the business world, and the perfect world will be analyzed. The political sphere is important because it is the framework in which the business world must operate. For this reason, businesses are behooved to do business in harmony with legislation on the one hand and on the other legislation should also not be so far removed from reality that the gap becomes insurmountable. The environment is an important factor because society must live from what the environment provides it.

The concept of a perfect "green world" can be traced back to the transcendentalist movement of the early 19^{th} century – the utopian vision of self reliance and self sufficiency as in the examples of Thoreau and Emerson. The 18^{th} century transcendentalist movement however stemmed from a reactionary response to the industrialization of the 18^{th} and 19^{th} century which expressed "civil disobedience" in wanting to go back to the roots of society before the smokestacks began belching black smoke into the skies. The idea of a green world was further developed in the mid to late 20^{th} century when indicators began to arise that the manner in which humans were interacting with the environment was not sustainable.

The oil crisis of the 1970s brought this conflict between the environment and mankind's use of it to the limelight and resulted in the birth of the ecological movement. In contrast to the earlier movements, which were caused by arguably less life-threatening conditions, the ecological movement of the 1970s declared an ecological crisis of our planet and highlighted the need to actively change human behavior in order to combat this crisis, or prevent it from becoming irreversible.

These changes which were called for by the ecological movement slowly pervaded the political sphere in the 1980s, with its concepts beginning to materialize in international treaties and national legislation. In this vein, the 1987 report by the Brundtland commission and their document on what they called "our common future" resulted in the definition of what sustainable development is finally making it into written form. This definition can be found paragraph 1 of the 1987 report, which reads:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
>
> 1. the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
> 2. the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.
>
> Source: Brundtland Comission, 1987.

A host of other legislation and international treaties came shortly thereafter at the Earth Summit which was held in Rio de Janeiro in 1992. The summit, which was held by the United Nations, resulted in documents and international treaties which further highlighted mankind's relationship with and responsibility to the environment. The United Nations Framework Convention on Climate Change (UNFCCC) was established as well as the Convention on Biological diversity, both of which are legally binding agreements with more than 192 countries worldwide as parties. Also resulting from the conference were other documents such as Agenda 21 which include environmental considerations such as the protection of the atmosphere, protection of ecosystems, conservation of natural resources. Also established were important principals such as the precautionary principal in an attempt to prevent serious or irreversible damage to the environment.

The concept of sustainable development as first envisioned by the Brundtland commission and elaborated on by the United Nations and other state and international actors is an overarching one which transcends borders, industrial sectors and peoples; one which is truly global in nature.

The ICT sector has placed a large burden on the environment in terms of resources from lead to nickel to cadmium required to support the manufacture of products. Additionally indirect consequences such as high energy usage which leads to increased emissions as well as problems such as the end of life treatment of the products. This work will focus on the Information and Communication Technologies (hereinafter referred to as ICT) sector, a sector which has experienced massive growth in the past few decades and its relationship to the environment. The historical development of the energy demand of ICT within the last three decades will be examined as well as what effect development has on overall energy demand. Just as importantly how these effects be mitigated or reversed through the (possibly increased) usage of ICT will be examined.

Structure

This work will serve two functions, first as a survey of relevant information regarding ICT and energy usage related to its use. The second function will be to synthesize this collected information and analyze it in a comparative and analytical fashion, as well as make recommendations for the more intelligent usage of ICT in the future. The major topics of this work are separated into the following chapters which are briefly outlined below.

The second chapter, The State of ICT, is a survey of the current state ICT sector and the technologies which fall under this classification. Computer technologies as well as mobile technologies will be described with their relationship with the environment. The energy usage of ICT technologies will also be presented, along with some of the important trends in the sector which have a major effect on energy usage and or the environment. The rebound effect, which originated in the energy sector, will be presented and its importance in the ICT sector will be explained. Lastly the current growth trends based on available sales and distribution data will be examined.

Chapter 3, ICT and Energy Usage, explores ICT and its relationship with energy usage. This chapter will put the energy usage in a global context using economic and statistical data about energy consumption in the world in total and explain energy saving techniques, technologies, and functions have developed within the last three decades. Concepts which are directly related to energy usage will be presented.

Legislation Affecting the ICT Sector is a survey of legislation which is of relevance in the ICT sector. The European concept of Ecodesign and the life-cycle / cradle to grave approach will be explored as well as the concept of Waste Electrical and Electronic Equipment (WEEE) and what this means for the environment. The different methods of preventing WEEE, or safely collecting and recycling from the appropriate legislation are presented. The concept of standby power, what it means for energy consumption of ICT and legislation minimizing wasted standby power are explained. U.S. legislation as well as EPEAT and Energy Star systems, also originating from the U.S. are the final two concepts introduced.

Research and analysis of historical power consumption trends as well as Moore's law and its relationship with energy demand is examined in Analysis of ICT Energy Demand. Finally in Suggestions for ICT and Sustainability ICT and its role in sustainable development will be presented, analysis and suggestions will also be included.

Methodology

The goals of this work are to collect and synthesize data about the usage of energy, including electricity and other (i.e. mineral) resources consumed in their production and during usage. As mentioned in the above section, this work will survey relevant information regarding ICT and energy usage related to its use. A synthesis of this information will be made and will be analyzed in a comparative and analytical as well as quantitative and qualitative manner. The focus of this work will be energy usage by ICT devices. This analysis manifests itself in topics from the energy usage of individual device class, i.e. mobile phones, to the energy usage of more complex systems such as data centers and mobile telecommunication networks.

Scope and Data Gathering

Data will be taken from available sources and synthesized in a manner which puts the energy usage into the big picture – i.e. examining first order, second order, and third order effects. Examining all of these effects will result in the systemic analysis of energy usage in ICT. First order, second order, and third order effects are explained in further detail in Chapter 2.

Data was collected from a variety of proprietary and public sources. Data regarding legislation is freely available and was retrieved from the respective responsible authorities in the – i.e. the U.S. Federal and State governments as well as the European Union. Sales and technical data was collected from a variety of sources including some which are not freely available to scholars or researchers as well as from journals which are published and widely available in the scientific community.

Chapter II

The State of ICT

> *Information and Communication Technologies are defined as "information technology plus telecommunications equipment and telecommunications services. Information technology refers to the combined industries of hardware for office machines, data processing equipment, and data communications equipment and of software and services".*
>
> *(EITO, 2002)*

ICT and the Environment

The manner in which ICT is employed in today's economy does not actively contribute to environmental sustainability. ICT can however be used in a sustainable fashion, for example to achieve dematerialization, where replacing tangible goods with electronic ones contributes positively to environmental protection. Unfortunately, for a host of reasons, which will be examined in this chapter, including the rebound effect and others, ICT does not always have a positive environmental impact. Three levels of effects or impacts, described by Lorenz Hilty below, must be taken into consideration when thinking about ICT and the environment.

These effects are:

- 'First-order' or 'primary' effects: effects of the physical existence of ICT (environmental impacts of the production, use, recycling and disposal of ICT hardware).
- 'Second-order' or 'secondary' effects: indirect environmental effects of ICT due to its power to change processes (such as production, transport or consumption processes), resulting in a decrease or increase of the environmental impacts of these processes.
- 'Third-order' or 'tertiary' effects: environmental effects of the medium- or long-term adaptation of behavior (e.g. consumption patterns) and economic structures to the availability of ICT and the services it provides.

  Source: Hilty, 2008.

As a general indicator of the role of ICT in environmental protection or degradation Hilty, et al., appraise the environmental impact of ICT until the year 2020 as such:

> … the influence of ICT applications turned out to be very different depending on the framework conditions. Under conditions generally conducive to environmental protection ICT reduced the overall environmental impact by around 20%, whereas under the least favorable conditions ICT was responsible for 30% of the additional environmental impact. Therefore it is the framework conditions that decide whether the ecologically positive or negative sides of ICT will prevail. That should suffice to disprove extreme positions such as "ICT will save the environment by itself" and "ICT can only hurt the environment[1]".
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> Source: Hilty, 2008.

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[1] These simulations in indicating the role of ICT in environmental protection or degradation conducted by Arnfalk et al., Erdmann et al., and Hilty et al. were executed under two very different types of prevailing conditions. The first variation was a "continuing expansion of ICT applications (such as process optimization in industry, traffic management, heating controls, virtual meetings, etc.)". The second variation simulated business as usual (BAU) as of the year 2000, i.e. ICT usage remained unchanged from its 2000 level until the projection year 2020.

ICT and the Information Society

The concept of an Information Society is frequently associated with some of most prominent characteristics of the contemporary effect of ICT in the world – these characteristics are:

- an increasing gross national product through the use of information technologies,
- an increasing private and business use of information obtained through digital means, and
- coordination in all facets of modern day society increasingly occur with no dependency on temporal or spatial factors.

  Source: Memorandum Nachhaltige Informationsgesellschaft, 2004.

Dompke et al, 2004 think that this appraisal of the current state of the Information Society harbors the danger that the effects of ICT on society will be viewed as unchangeable and unavoidable. They then propose a definition of what an Information Society should be in order to promote sustainable development. They define it as "a society in which every individual can satisfy his or her wants without infringing upon the basic democratic rights of others" (Dompke et al., 2004). The environmental effects associated with the manufacture and usage of ICT are also covered by the previous definition.

Three further criteria are outlined by Dompke et al. which ICT (in the larger framework of sustainable development) should fulfill. They are:

1. Human Compatibility – i.e. no human being should be harmed in any capacity and the dignity of all humans should be preserved,
2. Social Compatibility – i.e. the social system resulting from the relationships of human beings with each other and participation should be preserved,
3. and Compatibility with Nature – i.e. the environment should not be permanently or irreversibly damaged and natural livelihood should be conserved.

   Source: Memorandum Nachhaltige Informationsgesellschaft, 2004.

Dematerialization

Dematerialization is a trend in industrialized countries caused by the structural shift in the economy from energy-intensive manufacturing to energy-frugal services (Herring and Roy, 2007). It consists of replacing real products with virtual ones – as in the example of digital books or digital music instead of printed books, CDs or records. Further dematerialization of an economy points to less resources being used in that economy. For example if a book publisher shifted their publishing to be completely digital and paperless that publisher would no longer be using paper resources.

Eurostat, an appendage of European Commission's which collects and analyzes statistics, reports a range of data on the usage of the Internet by individuals for a range of activities which fall under the category of "dematerialization". This includes the use of the Internet:

- for finding information about goods and services,
- for reading/downloading online newspapers/news magazines,
- for Internet banking,
- for selling goods and services (e.g. via auctions),
- for formalized educational activities (school, university, etc.),
- for doing an online course (of any subject),
- for dealing with the government,
- for ordering/buying goods or services, over the Internet, for private use, in the last 3/12 months, including the type of goods and services ordered, and
- goods and services ordered over the Internet that were delivered or upgraded online, including films or music, books, magazines, newspapers, or e-learning material as well as computer software (video games included).

Source: OECD, 2009.

Computer Technologies

A computer is defined by the European Commission as: A device which performs logical operations and processes data. Computers are composed of, at a minimum:

1. a central processing unit (CPU) to perform operations,
2. user input devices such as a keyboard, mouse, digitizer or game controller. and
3. a computer display screen to output information.

For the purposes of this specification, computers include both stationary and portable units, including desktop computers, integrated desktop computers, notebook computers, small-scale servers, thin clients and workstations. Although computers must be capable of using input devices and computer displays, as noted in numbers 2 and 3 above, computer systems do not need to include these devices on shipment to meet this definition (European Commission, 2009).

The personal computer (PC for short) is, next to the mobile phone, one of the most common devices in the western world. Everyday life has become so intertwined with the use of PCs that it is hard to imagine a life without them. Microprocessors, the integral component of PCs are even more widespread than the PCs themselves, with some estimates saying that only 2% of the microprocessors in the world are in PCs with the remaining 98% being found in embedded and integrated ICT devices (Hilty, 2008). Because the massive growth of the distribution of PCs partially due to the rebound effect (explanation found in a later section of this chapter) and other factors in the private and commercial sector, it is crucial to focus on regulation, manufacturer default settings related to energy, and default configurations on the part of computer manufacturers to curb energy use on a unit-by-unit basis. This unit-by-unit basis when multiplied by the economies of scale will result in real and significant steps toward reducing the environmental impact of the PC.

Classifications

For the purpose of rating and regulating computing equipment it is generally separated into seven somewhat discreet categories. These categories are found in Table 1: PC Classification:

Table 1: PC Classifications

Desktop Computer	The main unit is intended to be in a permanent location and is not designed for portability. This is the most broad categorization covering both home and office applications. Requires an external display device which is not included in the category.
Small-Scale Server	A computer which typically uses desktop components but is designed to be a storage host for other computers – providing network infrastructure services. However, these computers are not engineered with this purpose in mind. They are intended to be operational 24 hours per day 7 days per week with low unscheduled downtime.

Game Console	A standalone computer-like device whose primary function is to play video games. They contain the same components as a typical computer (processor, system memory, video processing, optical and/or hard drives, etc…) but do not use a typical computer operating system. Handhold gaming devices are not covered in this category.
Integrated Desktop Computer	Generally provide similar functionality as a desktop system except that the computer and computer display function as a single unit which receives power through a single AC cable.
Thin Client	An independently powered computer which relies on a connection to remote computing resources to obtain primary functionality. Intended for use in a single location.
Notebook Computer	A computer designed specifically for portability and can be operated for an extended period of time without an AC connection. Touch Tablet PCs which may use touch sensitive screens fall under this category.
Workstation	A high-performance, single-user computer typically used for graphics, CAD, software development, financial and scientific applications which are calculation/computing intensive.

Source: Energy Star, 2008.

Using historical sales data taken from US Census Bureau the approximate distribution of computers in 2004 was 55.3% Desktop / Integrated Desktop, 23.0% Small Scale Server, 17.8% Notebook Computer, and 3.9% Workstation[2] (US Census Bureau, 2005).

Power Consumption

The computing power of PCs of today is achieved by a semi conducting microchip known as a CPU (short for central processing unit). The CPU is in turn powered by a power supply which takes alternating current from the power grid and converts this power into direct current (DC) which can be used by the digital components of the

[2] Newer data is available in the report, 2004 was however the only year available which had a breakdown of distribution of the classifications of computers. More recent data was aggregated and therefore a statistical breakdown was impossible using the data.

computer including graphic cards, storage devices and the CPU. PCs require DC power due to the nature of the way in which they function – that is that they are digital devices. Digital devices require the steady voltage which AC by its nature of being alternating cannot provide. Due to the conversion from AC to DC power is lost in the form of heat and entropy[3].

Despite the unavoidable loss of energy at the power supply during voltage conversion, as PCs became more and more widespread and commercially available, there were a number of improvements which helped to reduce the usage of power while also allowing for increases in the performance of the processors. Today's typical PC power supplies supply +12, +5, +3.3, 0, -5 and -12 DC voltages. Early CPUs were powered by a DC +5 volt current. As power consumption became more of a concern newer processors began to use +3.3 and lower voltages. At any given current level a processor using 3.3 volts will consume less power than the same processor if it is using 5 volts (PC Guide, 2010). Of course this was only one small step toward reducing the energy consumption of PCs.

Data Centers and Cloud Computing

An information society which has information at its fingertips 24 hours a day 7 days a week has become, at least in the developed western world, the norm rather than the exception. With this demand comes additional energy demand to store and make available all of this information on a constant basis. Data centers are of huge importance when looking at the energy consumption of ICT. Their energy demand and the related emissions are responsible for more than half of IT-related electrical costs (Ruth, 2009). A Gartner study found that data centers, with their associated servers, air conditioning, fans, pumps, uninterruptible power supplies, and so on, use 100 times the energy per square foot of an office building (Capuccio and Craver, 2007).

Energy usage related to this information society has grown massively and one of the biggest vaults in which the information that is stored and served is data centers. Computers in data centers can be arranged in a cloud, therefore cloud computing

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[3] The efficiency of the power supplies converting the AC to DC power has reached around 90% in modern power supplies, but the entropy can never be eliminated totally i.e. the theoretical maximum is on the order of 99.99998%.

can have a direct impact on the energy usage of data centers. The term cloud computing can be a rather convoluted one. An earlier version of the term referred to single virtual system which could serve all of the user's needs based on the actual demand for the services[4]. As in the example of Amazon's Elastic Compute Cloud which was launched in 2006. The service which it provided was "cheap, raw computing power that could be tapped on demand over the Internet just like electricity" (Hof, 2006). I.e. if a small start-up company had a website which did not have many technical demands it would not make financial sense for that company to rent too much computing power or bandwidth[5]. If one rents a dedicated server and the server sits idle 99% of the time a large drain of resources occurs in terms of material as well as financial resources.

Recently, more blanket terms have been coined – as in the Greenpeace March 2010 report: "Make IT Green – Cloud Computing and its Contribution to Climate Change". In this report the term cloud computing is defined as:

> … a metaphor for the Internet, [the cloud] is based on an infrastructure and business model whereby – rather than being store on your own device – data, entertainment, news and other products and services are delivered to your device, in real time, from the Internet.
>
> Source: Greenpeace, 2010.

Regardless of how the term is defined – in its original form or in a modified form in order to make a point – it is immediately apparent that the concept of cloud computing is directly connected with energy usage, but depending on how you define the term the effects can be different. The services offered by Amazon were offered as an alternative to dedicated or shared hosting[6] environments, both of

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[4] A virtual system consists of many different physical computer servers, which operate in a synchronized fashion using special software to offer transparent, scalable services to the user.

[5] To draw an analogy – if one wanted to transport a crate of beer over a long distance it would make much more sense to do this with a small vehicle instead of a 47 foot semi-truck. The 47 foot semi-truck represents a server or bandwidth with vastly underutilized resources.

[6] Dedicated and shared servers are servers which are found in data centers with a direct, high speed connection to the Internet. A dedicated server refers to a single physical machine which a user purchases for exclusive use – no other customers will be using the computer or its resources. A shared server is a single physical server which is used to offer services to

which were not optimized to make the best use of available resources across multiple physical computer systems. The scalable, shared cloud system offered by Amazon was designed to make better use of physical resources on a large scale. This goal had the side effect that resources and thus energy could be more efficiently allocated and thus better used across a cloud system. On the other hand, if one takes the term cloud computing to be a metaphor for the Internet then these presuppositions no longer hold true and the term encompasses a much bigger infrastructure and therefore energy demand.

Mobile Telephones

Digital mobile telephony comprises a very important portion of what is known as ICT. Mobile telephones (sometimes known as cellular phones) are increasingly popular in both the developing and developed world. According to data from the United States Environmental Protection Agency acquired through the Consumer Electronics Association, domestic cell phone sales had increased more than eight fold in the decade from 1997 to 2007, with sales starting at 22.2 million units increasing to 181.9 million units in 2007 (US EPA, 2007). For an idea of how pervasive mobile technologies are in all regions of the world see Figure 3: 2007 ICT penetration rates per 100 inhabitants on page 26. This section focuses only on digital mobile technologies because they are the predominant mobile technology which can be found today[7]. It should be noted as well that digital mobile technologies are generally more efficient than their analog counterparts.

Mobile Network Structure

In order to understand the importance of digital mobile technologies in the context of energy usage it is important to look at how the digital mobile network and its energy using components. A cellular network consists of, in its simplest form, a base station

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many different users. A shared server will typically use less energy per user because of higher utilization rates but at a tradeoff of performance if many users are using the system concurrently. Both dedicated and shared servers share the characteristic that when their resources are exhausted they cannot borrow resources from another server.

[7] According to the International Telecommunications Union, a UN Agency which is tasked with identifying, defining and producing statistics covering the telecommunication/ICT sector in its 2008 Country Data Statistics 73.4 percent of mobile networks worldwide were digital with the remaining percentage being analog.

and a digital mobile device. Both the base station and the digital mobile device require energy to operate, but not in equal proportions.

The base station (also referred to as Network Equipment) can be broken down into three different types of equipment, listed below:

- BTS, Base Transceiver Station
- MSC, Mobile Services Switching Center
- BSC, Base Station Controller

These components are linked in the following fashion: In order for cellular devices to have connectivity and function wirelessly they need to connect to a Base Transceiver Station. One BTS is only effective in a particular geographic location and many are needed in order to enable the seamless functioning of mobile phones over long distances. The density of BTS is determined by the geographic location as well as the number of subscribers which will be using the cellular services. Base Station Controllers are needed to control many different BTS and link them together into a web of mobile connectivity. The Mobile Switching Center is the bridge between the mobile telephone subscribers and the wireless and wired network. The MSC and other network equipment all need electricity to operate and this part of the infrastructure (Schaefer et al., 2003). As Schaefer, Weber and Voss point out in their article: "it is not sufficient to look at the millions of handsets to analyze the energy usage of cellular telephony, but the network equipment also has to be included.

Rebound Effect

The concept of the effect originates from the energy sector, but is of increasing relevance for the ICT sector. In the energy sector the growth of energy productivity (per gross domestic product per total energy consumption) in recent history was overshadowed by sheer growth in GDP. This meant that even though energy production was becoming more efficient (and inexpensive) the end result was that more energy was being consumed rather than energy being saved by the boost in productivity. This subsequent growth in consumption negated any positive effects which would have resulted from the increase in efficiency. This growth in consumption due which is related to efficiency increases is known as the rebound effect.

Rebound Types

Rebound effect is frequently mentioned in the concept of ICT, and like any phenomenon which is not based in science but rather in human behavioral patterns is very complex and unpredictable. The three different types of effects caused by the rebound effects are direct effects, indirect effects, and economy wide effects. Direct effects from the rebound effect are the ones which were already highlighted in the previous paragraph – they are due to a consumer's desire to use more of a product or service due to a lower cost. Indirect effects are ones which do not directly result directly from cost savings, but rather due to the fact that the money saved by efficiency is used to spend somewhere else which consumes energy. Economy wide effects are the changes which are caused in the economy by the innovation. These economy wide changes are brought about by changes in consumer preferences and/or social institutions (Herring & Roy, 2007).

The rebound effect has been felt particularly strongly in the ICT sector due to the cost reductions which went hand in hand with the exponential rate of growth predicted by Gordon Moore[8]. Specifically, the advances in technology and exponential growth in performance which have been achieved have also been marked with an almost constant trend in prices for ICT products. This phenomenon of receiving more performance for the same price can be said to be analogous with the rebound effects as experienced in the energy sector – the performance improvements allow us to receive more user utility without additional investment. The result is increased user utility and increased demand (Plepys, 2002).

ICT Growth Trends

Information and Communication Technologies are a sector which have, in the last two decades not experienced any significant lull in growth, and according to sales and market predictions this is a trend which will continue into the foreseeable future. For example, according to the "SMART 2020" report prepared by The Climate Group the number of PCs globally is expected to increase from 592 million in 2002 to more than four billion in 2020 (The Climate Group, 2008) an increase of almost 7-fold in just shy of two decades.

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[8] His prediction, that the density of semiconductors in a chip and thus performance will double every 24 months is examined later in the ICT and Energy Usage Chapter.

ICT Spending

According to market statistics from Gartner in a report which was published in 2001 the worldwide average for increase in hardware sales from the 2001 until 2005 time period should be approximately 5.90 percent with the lowest growth rate in the Rest of World[9] and the highest in Latin America. The table below shows the relative growth rates within the ICT sector. In this prediction hardware[10] is generally the slowest growing portion of ICT and "intangible" products such as software and services have the highest growth rates. Telecommunications[11] products also showed a growth rate on par with the intangible services.

Table 2: ICT Spending Forecast 2001 to 2005

Hardware	*Minimum*	+1.89%	*Maximum*	+15.07%	*Average*	+5.90%
Software	*Minimum*	+12.31%	*Maximum*	+20.49%	*Average*	+14.14%
Services	*Minimum*	+11.13%	*Maximum*	+26.22%	*Average*	+14.63%
Telecom	*Minimum*	+7.44%	*Maximum*	+19.24%	*Average*	+13.35%
All IT	*Minimum*	+8.61%	*Maximum*	+19.06%	*Average*	+12.60%

Source: Gartner, 2001.

Despite these rather rosy predictions displayed in Table 2: ICT Spending Forecast 2001 to 2005 from 2001, the reality of the 2007/2008 financial crisis and difficult market conditions caused a 5.5 percent decline in IT spending from 2008 to 2009 (Gartner, 2010). Gartner predicts, however, that growth will rebound to 6.2 percent by 2010 – predicting further that the strongest sector will be national and international government IT spending.

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[9] For this study Rest of World referred to countries not including the United States, Canada, Latin America, Western Europe, Central and Eastern Europe, Japan and Asia/Pacific.

[10] Hardware includes PCs, workstations, servers, server appliances, storage subsystems (including appliance/fabric storage as well as direct attached storage systems and their software systems), copiers and printers.

[11] Telecommunications devices include Telecom Equipment such as Carrier equipment, Premise-based Equipment, Remote access equipment and Mobile handsets. Telecom services are also included – consisting of Fixed voice services, Fixed data services and Mobile services (Gartner, 2010).

The conclusion which can be drawn from the above ICT spending and market conditions is that while the global economy continues to expand that the demand for ICT will follow. Furthermore, as one of the goals of many international agreements, such as the Rio Declaration[12] is to promote economic growth, it is a reasonable assumption that given recent trends to assume that the demand and spending for ICT will increase as well.

Historically sales have increased in a linear scale since the introduction of the PC in the late 1970s with laptop sales beginning to take off in the mid 1990s. Figure 1: Historical PC Sales in the U.S. and Figure 2: Historical PC Penetration in the U.S. both show the historical development of the penetration rates and sales (in units) of PCs (including desktops and laptops in the United States until 2008.

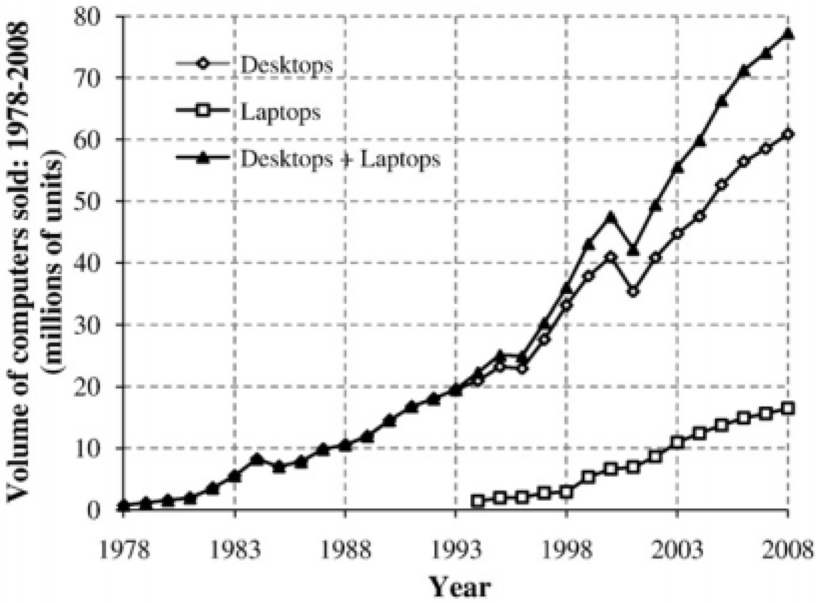

Figure 1: Historical PC Sales in the U.S.

Source: Yang and Williams, 2009.

[12] The specific wording of Principal 12 of the Rio Declaration also emphasizes that economic growth needs to lead to sustainable development as well.

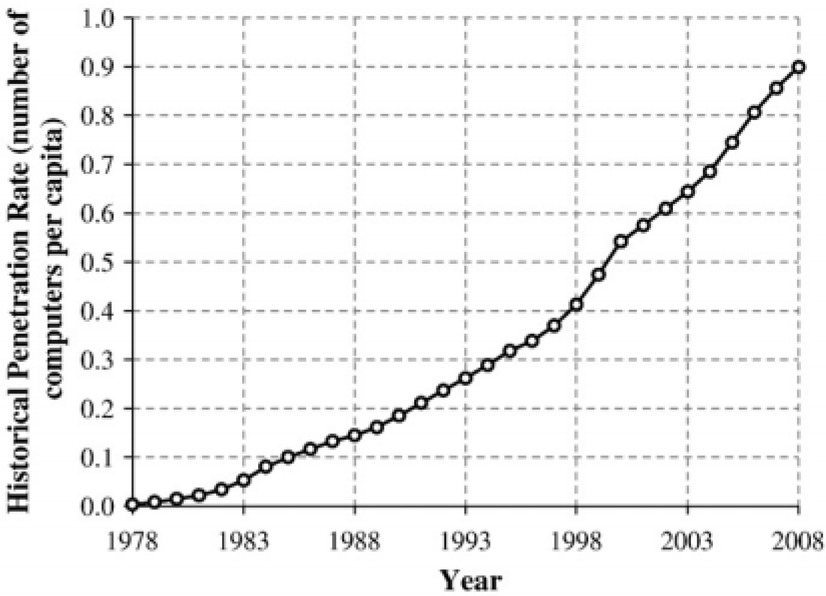

Figure 2: Historical PC Penetration in the U.S.

Source: Yang and Williams, 2009.

Developing vs. Developed Countries

In the "Key Global Telecom Indicators for the World Telecommunication Service Sector" statistics the ITU follow statistics in five different categories of ICT – fixed broadband subscriptions, fixed telephone lines, mobile cellular subscriptions, mobile broadband subscriptions, and estimated internet users. The indicators predict that there will be an increase in all five categories, with the fixed telephone lines being the slightest increase. Estimated Internet users in developing countries surpassed that of developed countries in 2007, and will rise at a rate faster than that of the developed countries if future growth follows historical trends. The number of mobile phones subscriptions in developing countries is growing at a much higher rate than in developed countries. Mobile as well as fixed broadband subscriptions are both on the rise in developed as well as developing countries (ITU, 2010). More information can be found in the appendix Key Global Telecom Indicators.

Desktop versus Notebook Distribution

In 2002 the most widespread type of computer was a desktop computer with a CRT monitor – representing 91% of the total, with desktops with LCD monitors at 6%, and laptops at 2% (The Climate Group, 2008). The Climate Group predicts that the desktop PCs that dominate today's market will be replaced by laptop computers if the adoption rates continue as forecasted – with almost two thirds of computers being laptops by 2020 (The Climate Group, 2008). The data from Figure 1: Historical PC Sales in the U.S. confirms the upward trend of laptop sales from 1998 to 2008. It is certain however that CRT monitor is fading into antiquity and will slowly but surely be replaced by the less energy intensive LCD monitor. Unfortunately, this substitution trend adds to the mounting problem of e-waste[13], which is addressed in the chapter on Legislation Affecting the ICT Sector.

Demographic Change

Social and demographic changes have been experienced to a high degree in recent history. These demographic changes will undoubtedly have a significant effect on the demand for, and resulting prevalence and usage of ICT. In the United Kingdom, for example, the number of households, all which require their own appliances like TV, computer, and telephone, has increased over the last 30 years while the average size of the household has decreased (from 3.0 in 1961 to 2.4 in 2004). These increases are attributed to changes in the social behavior, the tendency of children to leave their parental household sooner and the elderly to live alone and not with an extended family[14] (Loveday et al., 2008). If trends like this continue then it will impact the distribution and energy usage of ICT in a significant manner.

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[13] "e-waste" is an umbrella term with can also be substituted with others such as "Electronic waste", "e-scrap", or "Waste Electrical and Electronic Equipment (WEEE)" and loosely describes discarded, surplus, obsolete, or broken electrical or electronic devices (Wikipedia, 2010).

[14] It is important to note that this trend of increasing numbers of households was observed as being "rather unusual in that the number of households has increased much more rapidly than the population" (Van Diepen, 1998).

Chapter III

ICT and Energy Usage

> *A 2007 study by Gartner suggests that approximately 2% of CO2 emissions were caused by the ICT sector – a number which was comparable to the emissions by the aviation industry*[15]
>
> *Gartner, 2008*

This chapter will serve to provide an overview of relevance of ICT in global energy demand. Information and Communications Technologies and their relevance to energy demand will be examined on an individual ICT device class basis using published and available data related to energy usage in those sectors. Detail regarding the more precise usage of devices included in ICT will be looked at in Chapter 5: Analysis of ICT Energy Demand.

Using available energy consumption data from the Environmental Change Institute it is estimated that approximately four percent of domestic energy usage in the United Kingdom was due to consumer electronics such as TV, cassette players/radios, Hi-

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[15] The two percent figure includes the in-use phase of PCs, servers, cooling, fixed and mobile telephony, local area network (LAN), office telecommunications and printers. Gartner also included an estimate of the embodied (that used in design, manufacture and distribution) energy in large-volume devices, namely PCs and cell phones. It also included all commercial and governmental IT and telecommunications infrastructure worldwide, but not consumer electronics other than cell phones and PCs.

fis, and VCR. Other ICT related devices such as phones, PCs, printers, scanners, etc… were estimated to be below two percent[16].

Origin of ICT Demand

ICT demand has originated primarily from the rich western economies, but their growth is no longer limited to these markets. Increasingly as the western market becomes inundated with ICT there is still growth in markets where ICT has traditionally been less common. The Smart 2020 report predicts growth in developing economies such as China and India. According to the report, "Just one in 10 people owns a PC in China today; by 2020, that will rise to seven in 10, comparable to current ownership rates in the US. In just 12 years' time, one in two Chinese people will own a cellular phone and half of all households will be connected by broadband. It will be a similar story in India. By 2020, almost a third of the global population will own a PC (currently one in 50), [and] 50% will own a cellular phone".

In the developed world ICT can be thought of as the thread that holds together the fabric of the information society. It pervades almost every aspect of life from manufacturing to sales to transportation to government. This is becoming increasingly apparent as the world becomes more interconnected in economic terms and information exchange.

World Energy Outlook

Electrical power is the primary source of energy which is consumed by ICT during its lifetime. In their 2009 annual International Energy Outlook report the United States Department of Energy they predicted an annual increase of 2.4% in electricity generation (demand) from 2006 until 2030. Beginning in 1990 the world demand for energy has increased only by 1.9 percent per year whereas the yearly percentage of electrical generation has increased by 2.9 percent per year (US DOE, 2009). The report predicts that this trend in electricity generation will continue until 2030. The report also predicts a growth in the total electricity demand by non-OECD developing markets – according to the predictions this will grow from 45 percent of

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[16] In the analysis mobile phones, computers, monitors, printers, fax/scanners, and telephones were grouped together other miscellaneous household appliances such as personal care products, DIY equipment, vacuum cleaners, security systems, etc… This category together accounted for a 2% energy usage.

total electricity demand to 58 percent in 2030. This poses problem if the main growth market for ICT is in developing markets where the energy share is increasing and those markets experience the rebound effect to the same degree it was in the developed markets.

ICT Energy Outlook

The predictions for the development of energy demand by ICT generally point to an increase and vary between plus 5% to plus 23% according to the European Commission Joint Research Centre, with the maximum energy usage by the ICT sector lying at around 3% of total energy usage by 2020 (Hilty et al., 2004)[17]. While ICT electricity demand will increase, there is hope that they can contribute to an overall reduction in electricity demand. For example, the host of goods and services which are pervaded by ICT can be optimized through the increased and more intelligent use of them. According to Hilty et al. these areas where ICT could affect a decrease (or in some cases increase) in total energy consumption include:

Table 3: ICT Impact on Total Energy Consumption

Supply chain management	Employment of ICT in supply chain management will reduce energy consumption as a result of more intelligent distribution of good where they are needed.
Teleshopping	Shopping without traveling reduces energy consumption as a result of reduced travel.
Telecommuting	Telecommuting is predicted to reduce energy consumption as a result of reduced travel.
Virtual meetings	Virtual meetings will also reduce energy consumption as a result of reduced travel.

[17] The high degree of uncertainty stems from the trade-off between two major trends in ICT. On the one hand the number of ICT products and their usage will increase but at the same time the energy efficiency of they are likely to become more energy efficient.

Virtual goods	Virtual goods (i.e. digital books, information systems or music) have a high positive effect resulting from avoidance of resource usage for a physical good.
Intelligent transport systems	By increasing the time efficiency in public transport energy is conserved.
Energy supply	ICT in the supply system are not predicted to have a major positive or negative impact.
Facility management	ICT in facility management are predicted to have a net reduction of energy consumption.
Production process management	ICT can help optimize the process, increasing yield but reducing energy demand.
and Time utilization effect	Time utilization is predicted to increase passenger transport growth due to the ability to be productive whilst traveling.

Source: Hilty et al., 2008.

Overall, the observations from Hilty et al. suppose a range of energy consumption impacts from ICT – ranging from a slight (less than 2%) growth of energy demand to a moderate reduction (around 16%) due to the combined effects of the factors named above in Table 3: ICT Impact on Total Energy Consumption. A more exact prediction regarding ICT can be found in the later in this chapter on the section ICT Energy Usage until 2020.

Information Technologies

When thinking about a computer, it may be easy to think that as with any other electrical device with a switch, it is either on or off. Fortunately, or unfortunately (for energy usage) this is not the case. Most electronic devices consume power even when switched off. This off or standby usage is, thanks to regulation and vendor initiative, usually kept to a minimum. Computers have multiple modes of operation which are well described in (but do not originate from) the Official Journal of the European Union. The modes are listed and paraphrased as found in Commission Decision 2009/489/EC below:

- Off Mode: The power consumption level in the lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer’s instructions.
- Sleep Mode: A low power state that the computer is capable of entering automatically after a period of inactivity or by manual selection. A computer with sleep capability can quickly ‘awake’ in response to network connections or user interface devices.
- Idle State: The state in which the operating system and other software have completed loading, the machine is not in sleep mode, and activity is limited to basic applications that the system starts by default.
- Active State: The state in which the computer is carrying out useful work. This state includes active processing, seeking data from storage, memory, or cache, including idle state time while awaiting further user input and before entering low power modes.

  Source: European Commission, 2009.

The fact that with electronic devices off does not necessarily mean zero power consumption illustrates the importance of these different states and the need to regulate these different states by legislation.

Power Management

One of the methods by which computers achieve power savings is by soft means, i.e. by integrating power saving hardware components with more effective software management of these components. An integrated approach is a new approach to reducing a product's energy consumption. This integrated approach is well illustrated by the following three points taken from Apple's 2010 "Designed to make a difference" campaign:

1. Use more efficient power supplies,
2. use components which use less power,
3. use power management software.

This so called integrated approach is also mentioned previously by Arndt Bode in his 2008 review of the "The Future of Computer Technology" scholarly article, which was originally written by H. Kaufmann in 1970. Bode points out that "developers of microprocessors no longer have the goal of achieving the highest absolute computing speed, rather of achieving the highest speed for the amount of energy used" (Bode, 2008). Citing the growing operating costs related to powering PCs, Bode also emphasizes the need to reduce the energy consumption of the individual components, as well as to design software in an optimized manner. This optimized software should recognize when components are not in use and not needed and automatically power them down.

Cellular Technologies

Cellular mobile telephones today are one of the most widely distributed forms of ICT across the globe. Cellular telephones have been in existence since the mid 1980s, with the first widespread usage happening in the 1990s and on. They are used from the Americas to Asia as well as in developing countries where high tech devices are not as commonplace. Figure 3: 2007 ICT penetration rates per 100 inhabitants shows the penetration rates of fixed telephone users, cellular subscribers, Internet users, and broadband Internet users for the six different regions named in the legend.

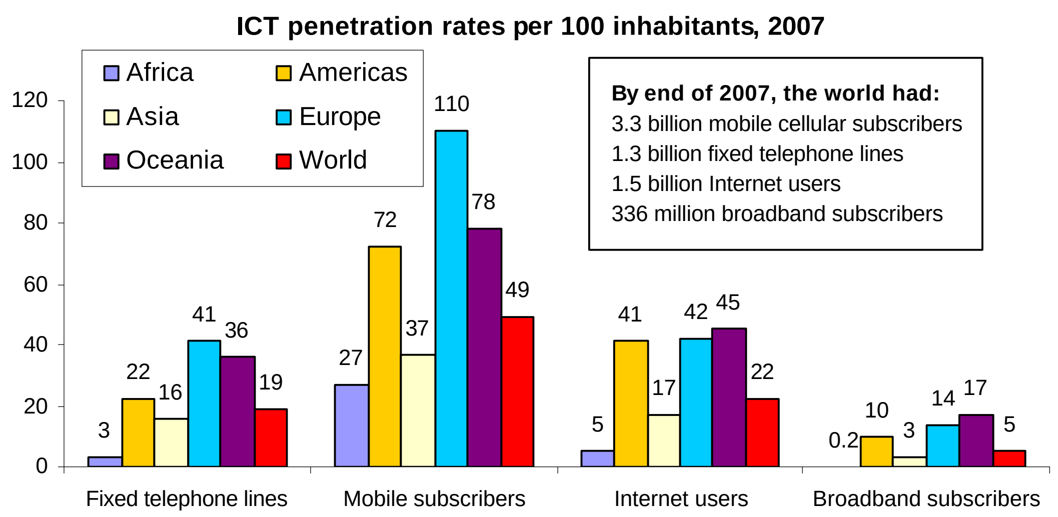

Figure 3: 2007 ICT penetration rates per 100 inhabitants

Source: International Telecommunications Union, 2010.

In the summary of the 2001 article "Energy usage of mobile telephone services in Germany" Schaefer, Weber and Voss they illustrate the significance of digital cellular technologies in the total energy usage in Germany. The article can be summarized as follows: The annual electricity consumption of the German cellular telephone sector was calculated to be around 726 GWh, which translated to 16.2[18] kWh per subscriber (without including the standby consumption of the chargers). To this end only 7 percent of the total energy usage of the cellular telephony sector was consumed by the digital cellular handsets and the remaining 93 percent is consumed by the network equipment. This annual consumption is estimated to be 0.13 percent of the total electricity consumption in Germany. However, these estimates do not include the standby electricity consumption of chargers which are left plugged in even when not charging a device. When the standby is taken into account the total electricity consumption increases to 1305 GWh which translates to 29 kWh per subscriber[19]. When including standby the percentage of electricity consumed by digital cellular handsets increases from the 7 percent named above to 45 percent of the total electricity consumed (Schaefer et al., 2001).

Schaefer, Weber and Voss went on to compare their results to a 1991 study which looked at one non-digital mobile network and showed a 65 kWh per subscriber electricity consumption rate including standby consumption. The increase in efficiency was attributed to the increase in the number of subscribers and the higher utilization of the digital mobile network, not to energy efficiency of handsets, chargers, or network equipment. The energy savings was attributed to higher utilization of the digital mobile networks and the fact that the electricity consumption of the infrastructure has not increased proportionally to the number of users.

Specific Energy Demand

This section will look at the energy demand of some of the most common classes of ICT devices which can be found in the developed and developing world today and analyze what their specific per unit energy demand is. Consumer devices as well as business usage such as data centers will be examined.

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[18] This is equivalent to a continuous power demand of 1.85 W when calculated out over a year.

[19] It should be noted that the calculations in the article were based on a 1.5 W electricity demand per charger during non-charging times (assumed to be 8604 hours per year). As is outlined in the Legislation Affecting the ICT Sector chapter the actual standby power requirements prescribed by legislation are a third of this estimate with many chargers consuming far less than that due to manufacturer initiative.

Monitors

In a 2002 study by the Energy Analysis Department of the University of California at Berkley it was found that LCD monitors are per area of display more efficient than CRT monitors. LCD monitors consumed on average 30 watts during normal usage (an *On*[20] state) whereas a CRT under the same conditions consumes 76 watts, as can be seen in Table 4: Monitor Energy Consumption.

Table 4: Monitor Energy Consumption (Watt)

Type	**CRT Monitor**					**LCD Monitor**			
Size	All	15"	17"	19"	21"	All	15"	17"	18"
Monitor *On* Power (W), with PC *On*[21]									
Average	76	58	61	85	95	30	20	35	54

Source: Roberson et al., 2002.

Desktops

Desktop computers consume on average more than laptop computers because of the higher number of components such as disk drives and/or optical drives as outlined in Table 1: PC Classifications on page 10. In Table 5: Desktop Energy Consumption (Watt) on the next page the results of the 2002 study by Roberson et al. are displayed showing a range of *On* state power consumption as well as the average consumption for the desktop PCs with the named processors.

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[20] The on state from the 2002 is classified as when the power button is in on position and the power indicator being green for desktops, and the same for monitors with the additional criteria of the monitor displaying an "empty desktop", as found at bootup (Roberson et. al, 2002).

[21] These numbers represent the amount of energy used by the monitor in normal use, i.e. when the monitor is connected to a computer and displaying information received from the computer.

Table 5: Desktop Energy Consumption (Watt)

CPU		**Measured Power**			
Brand, Model	Speed Range	Range	Average	Light Sleep[22]	Sleep
Intel Pentium 3	733-1000 MHz	28-47	38	32	13
Intel Pentium 4	1300-1800 MHz	59-94	67	62	3
AMD Athlon	1000-1400 MHz	93-117	104	32	15
Average		28-117	70	42	10

Source: Roberson et al., 2002.

Notebooks

Notebook computers typically have a much lower energy demand than desktop computers. This is by virtue of the fact that they are designed to be energy efficient and to run as long as possible without being connected to an AC power supply – only drawing power from an internal battery. Laptop computers examined in the 2002 study by Roberson et al. consumed from 15 to 25 watts when in the *On* mode, averaging 19 watts (Roberson et al., 2002).

Table 6: Notebook Energy Consumption (Watt)

CPU	Range	Average
Intel, Mac G4	14-25	19

Routers and Printers

Other ICT devices such as modems and printers also consume energy when plugged in to the power grid. The amount of energy consumed by printing devices varies, but ranges from 280W to 1270W when in use with standby and idle modes consuming between 2W and 200W (sust-it, 2010).

[22] Light sleep is a "higher low-power level" (Roberson et al., 2002) usually characterized by an almost instantaneous return to *On* mode. All tested desktops did not support light sleep, so this column is an average of a subset of tested desktops – 2 of 4 Pentium 3 CPUs, 4 of 6 Pentium 4 CPUs, and 1 of 4 Athlon CPUs.

The ubiquitous broadband router / modem consumes anywhere from 2W to 5W when plugged in[23]. Wireless and wired switches, hubs, and access points have similar power requirements, so there is no major difference in energy consumption between wired and wireless consumer networking equipment[24].

Data Centers

Energy usage in data centers is increasing immensely because of the demand for information and the increase in the number of virtual products. Data centers are collections of many individual server computers housed in the same building, which is specially designed in terms of power supply from the electrical grid, HVAC, and floor space to accommodate specially designed server computers. Because of the unique layout of data centers energy usage is measured in a different fashion from that of individual computers. Measuring the energy usage of data centers per computer or per user is too varied to be of use because equipment is not homogenous. Similarly, per user counts are difficult to determine because Internet users use many different resources spread over many different servers, so it is impractical to assign usage to a particular machine. For practical reasons, energy usage per square meter is a common measure, and the results of one study can be seen below in Table 7: Data Center Power Density. Computer power density represents the energy used by the computer systems themselves. Total computer room power density includes the energy for the computers as well as all services which are needed such as HVAC, UPS services, etcetera. Both of these only represent the energy needed per m^2 of the room containing the computers, not the whole building. Whole building power density is the energy required per m^2 of the entire building, not only including the rooms containing the computers.

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[23] This usage was calculated under different load modes of the modem – the lower limit of 2 watts was only reached when the router was providing no useful functionality (Internet or LAN) when under normal or full usage the measured value was between 4 and 5 watts (Fon, 2010).

[24] This assumption is made based on the voltage and amperage specifications of wired and wireless routers from various manufacturers.

Table 7: Data Center Power Density

	Power Density (W/m^2)	Light Sleep (W/m^2)	Sleep (W/m^2)
Computer power density	192	115	27
Total computer room power density	355	213	51
Building power density	140	84	20

The figure in the first column, "Power Density", in Table 7: Data Center Power Density are from a study done by Blazek et al., 2004, and the Light Sleep and Sleep columns represent an interpolated value based on proportional data from in the Desktop section above. Standby (sleep) demand of data centers can be interpolated by looking at the number of server computers which are contained in the computer room and applying a ratio which is appropriate for the standby versus the Light Sleep power demand of desktop computers. Values for standby and Light Sleep mode were both calculated to give an impression of what the same amount of equipment would use if it was in standby mode.

ICT Energy Usage until 2020

When looking at the energy usage by the ICT sector it is important to not only to look at the sector as a whole, but to look at a break down of the energy required for the individual device classes. For example, the consumption of mobile phones themselves only accounts for a very small percentage, less than 10% of the total energy required for their operation with the remainder being consumed by the mobile network itself. Therefore if one wanted to increase the energy efficiency of the mobile sector it would be prudent to do this in the mobile network, which consumes the most energy. When looking at computers it is important to differentiate the energy usage of the computer itself from the energy required to power computer[25] itself, and the display device as old style CRT display devices use more energy than newer LCD monitors. Of course individual computers are only a part of the problem – in a highly networked world the data centers which house data must also be taken into consideration.

[25] This term encompasses the logical unit of the computer, i.e. the processor, memory, internal storage, etc…

All available current data and forecasts on the demand for ICT indicate that the demand for ICT will not wane before 2020, and will most likely grow. Growth information from Table 2: ICT Spending Forecast 2001 to 2005 predicted a positive growth rate of hardware and telecom, the two most important parts of ICT when considering energy usage. With the exception of a lull of growth during the economic downturn of 2007/2008 ICT has consistently showed a positive growth rate. Even if Gartner's predictions of a 6.2 percent growth rate per annum does not hold true to it's maximum extent, it can be expected that ICT sales and distribution will continue to grow until 2020. Due to continued growth in the ICT sector the energy demand by ICT will increase as well due to the increased number of ICT devices – it will continue to consume an increasing percentage of total energy in developing as well as developed economies.

The most growth in energy demand will be in developing economies because as ICT continues to proliferate the economy the percentage of total energy consumed by ICT will increase will result from the increasing number of mobile devices as well as broadband connections. Energy consumption related to mobile networks will increase as the number of mobile subscribers increases due to the growth of demand for mobile phones in developing economies. As the number of Internet users goes up as predicted by the ITU the energy consumption by Internet related services such as networking and data storage will increase. While it is inevitable that the penetration rate of ICT in developed as well as developing countries will continue to increase until 2020, it is also plausible that as the trend for energy efficiency in the sector also takes hold that more energy efficient devices will help to mitigate the energy consumption. While the energy demand from ICT itself will increase, the employment of ICT in other sectors and in energy saving applications such as with smart grids, smart buildings, and smart appliances will help to lessen the overall energy demand. Overall energy demand will continue to increase, but at a decreased level in comparison to past growth trends due to the contemporary focus on sustainable development as well as the employment of ICT to achieve energy efficiency.

Chapter IV

Legislation Affecting the ICT Sector

Government and their regulatory bodies have provided demand as well as regulation in the ICT industry since its nascence. ICT was not widespread at its inception, and in the past environmental legislation regarding ICT was generally not as strict as today. There are many schemes out there today which regulate consumer electronics and ICT, these major sources of regulation are:

1. local and national regulation
2. International Organizations such as the International Telecommunications Union
3. Industry self regulation
4. energy labeling schemes

This section will focus on regulation and legislation in the United States of America, the European Union, as well industry self regulation.

Legislation in the European Union

The European Union regulates the energy usage by ICT devices using mainly EU wide directives. These directives originate from the European Commission and set limits for energy consumption, emissions and other performance specifications to which the manufacturers must adhere. The EU directives are not legally binding, but legislation must then be implemented by the member states themselves before a specified date in order to ensure compliance with the limits set in the directive. There are multiple directives aimed at cutting down the environmental footprint of ICT during its product lifetime.

Ecodesign

Ecodesign is a design concept aimed at reducing energy consumption by products such as household electrical appliances. It was introduced in 2005/32/EC adopted on July 6 of 2005. Under the scheme information concerning the product's environmental performance and energy efficiency must be visible if possible on the product itself, thus allowing the consumer to compare products based on energy efficiency before purchase (Ecodesign for energy-using appliances, 2010).

In principal the framework directive 2005/32/EC applies to all energy using products which are placed on the market. It also covers parts that are intended to be incorporated into products that are placed on the market as individual parts for end-users, the environmental performance of which can be accessed independently. The Ecodesign directive applies to all products placed on the EU market as well as to any products which are imported. Self-regulation by the industry is also included in the directive under Annex VIII. It stipulates that a self-regulation is a valid alternative to binding legislation, under certain conditions and in particular that voluntary agreements must achieve the same objectives as the binding legislation, include staged and quantified objectives and be open to new participants (Ecodesign - sustainable and responsible business, 2010).

Waste Electrical and Electronic Equipment

When WEEE is disposed of in an improper fashion, or treated without proper procedures, environmental harm arises. Devices like compact fluorescent lamps and flat-screens contain mercury and TVs lead – which can be released into the environment if proper disposal procedures are not followed.

Printed Circuit Boards

Cellular phones and computers all contain printed circuit boards (PCBs) which are the electronic heart of the device. Printed circuit boards are the primary source of toxic elements in ICT waste, and can contain up to 20 percent of elements which need to be recycled (copper).

Table 8: Representative Compositions of printed circuit boards (wt%) on the next page, taken from an article in the journal *Waste Management* by Ogunniyi, Vermaak and Groot represents the chemical content of PCBs. The "Materials" horizontal listing (%a through %g) represents the analyses from different authors listed

following the table, and the vertical listing breaks down the content of the on the horizontal axis is the percentage of the PCB which were found by different studies. According to the table PCBs generally contain a minimum of 16 elements and some percentage of plastics.

Table 8: Representative Compositions of printed circuit boards (wt%)

Materials	%a	%b	%c	%d*	%e	%f	%g
Metals (Max. 40%)[a]							
Copper (Cu)	20	26.8	10	15.6	22	17.85	23.47
Aluminum (Al)	2	4.7	7	–	–	4.78	1.33
Lead (Pb)	2	–	1.2	1.35	1.55	4.19	0.99
Zinc (Zn)	1	1.5	1.6	0.16	–	2.17	1.51
Nickel (Ni)	2	0.47	0.85	0.28	0.32	1.63	2.35
Iron (Fe)	8	5.3	–	1.4	3.6	2.0	1.22
Sodium Nitrate (Sn)	4	1.0	–	3.24	2.6	5.28	1.54
Antimony (Sb)	0.4	0.06	–	–	–	–	–
Gold/ppm (Au)	1000	80	280	420	350	350	570
Platinum/ppm (Pt)	–	–	–	–	–	4.6	30
Silver/ppm (Ag)	2000	3300	110	1240	–	1300	3301
Palladium/ppm (Pd)	50	–	–	10	–	250	294
Ceramic (Max 30%)[a]							
Silicon Dioxide (SiO_2)	15	15		41.86	30	–	–
Aluminum Oixide (Al_2O_3)	6	–	–	6.97	–		
Alkaline and alkaline earth oxides	6	–	–	CaO 9.95 MgO 0.48	–		
Titanates, Mica, etc…	3	–	–	–	–	–	–
Plastics (Max 30%)[a]							
Polyethylene	9.9	–	–		16	–	–
Polypropylene	4.8						
Polyesters	4.8						
Epoxies	4.8						
Polyvinyl-chloride	2.4						
Polytetra-?ouroethane	2.4						
Nylon	0.9						

[a] Shuey et al. (2006) from Sum (1991).
[b] Zhao et al. (2004).
[c] Zhang and Forssberg (1997).
[d] Kim et al. (2004).
[e] Iji and Yokoyama (1997).
[f] Kogan (2006).
[g] ICP–OES Analyses of cellphone printed circuit boards with hot aqua regia digestion.
[*] Incinerated printed circuit boards Product.

The recycling and reclamation of the elements listed in Table 8: Representative Compositions of printed circuit boards (wt%) is a difficult process and it is very difficult to reduce the elements to their purely elemental state. Digestion to reclaim these elements is achieved by dissolving the PCBs using sodium peroxide, hydrochloric acid and other combinations of chemicals and microwave energy. The particles liberated by this process tend to contain more than one chemical element. It is therefore impossible to convert these resulting alloy particles into their constituent elements.

The WEEE Directive

In order to reduce waste from ICT and other commercial products the European Commission passed a directive on waste electrical and electronic equipment in 2002. IT and Telecommunications are named specifically by the directive. The directive 2002/96/EC also is intended to promote the reuse, recycling and other forms of recovery in order to reduce the quantity of waste produced. The directive also aims to protect human health by taking measures to restrict the use of hazardous substances in electrical devices.

Separate Collection

The directive encourages member states to promote the design and production of equipment which takes into account and facilitates the dismantling and recovery of materials. Separate waste collection systems are a key point in this directive, and member states must ensure that:

- final holders and distributors can return such waste free of charge;
- distributors of new products ensure that waste of the same type of equipment can be returned to them free of charge on a one-to-one basis;
- producers are allowed to set up and operate individual or collective take-back systems;
- the return of contaminated waste presenting a risk to the health and safety of personnel may be refused.

  Source: European Commission, 2002.

Treatment and Recovery

Producers of electrical and electronic equipment must apply the best available treatment, recovery and recycling techniques. Such treatment is to include the removal of fluids and the proper storage of waste. For ICT equipment the directive stipulates that the rate of recovery by an average weight must be 75%, and the rate of component, material and substance reuse must be 65%. Additionally, producers must provide the financing for collection from the collection point at a minimum. They must also provide the funding for treatment, recovery and environmentally sound disposal of waste electrical and electronic equipment (European Commission, 2002).

Hazardous Substances

The usage of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers in electrical and electronic equipment must be replaced by other substances, this is known as a Restriction on the use of certain Hazardous Substances (RoHS). With a tolerance level of 0.1% for lead, mercury, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), and a tolerance level of 0.01% for cadmium. In addition, certain uses specified in the Annex to the Directive are tolerated.

Standby Power

In 2005 the European Commission passed Commission Regulation 1275/2005 which is based on the 2005/32/EC Directive sets Ecodesign requirements for standby and off mode electrical power consumption of household and office equipment. ICTs fall under this Ecodesign requirement. Computers and cellular phones consume energy even when they are not turned on and operational and the power supplies / converters draw energy even if they are not connected to the device that they power. As stated in point 4 of the opening of the Regulation:

> "…standby functionalities and off-mode losses occur for the majority of electrical and electronic household and office equipment products sold in the Community, while the annual electricity consumption related to standby functionalities and off-mode losses in the Community has been estimated to be 47 TWh in 2005, corresponding to 19 Mt CO2 emissions. Without taking specific measures, the consumption is predicted to increase to 49 TWh in 2020. It has been concluded that the electricity consumption of standby functionalities and off-mode losses can be significantly reduced".
> Source: European Commission, 2008.

The regulation aims to prevent unnecessary energy losses by stipulating that products enter a "0 Watt" consumption state when they are not providing any function. The goals for power consumption are in Table 9: Commission Regulation 1275/2008.

Table 9: Commission Regulation 1275/2008

1 year after the regulation is in force (by December 2009):	Power consumption in off mode must be 1 Watt or less;
	Power consumption in standby mode which allows reactivation must be 1 Watt or less;
	Power consumption in standby mode which allows reactivation and displays information (such as a clock) must be 2 Watts or less.
4 years after the regulation is in force (by December 2012):	Power consumption in off mode must be 0.5 Watts or less;
	Power consumption in standby mode which allows reactivation must be 0.5 Watts or less;
	Power consumption in standby mode which allows reactivation and displays information (such as a clock) must be 1 Watt or less.

Source: European Commission Regulation 1275/2008.

Legislation in the United States

Most legislation in the United States does not directly deal with ICT – but to some extent the industry is self regulating – as in pointed out by a Green Peace report some large online service providers elect to locate their data centers where they have easy access to renewable energy sources whereas others are not as picky and sign contracts with energy suppliers which obtain their electricity from coal and other non-renewable sources. There is a notable lack of appropriate state mandated legislation in the United States which regulates energy usage in ICT; the biggest source of regulation is still self regulation and energy labeling schemes which are discussed in the Energy Labeling Schemes and Self Regulation sections.

Energy and Security Act of 2007

In the USA legislation is made on the federal, state and local level. At the present time legislation which deals with energy usage and ICT is mainly on the federal level and even there very sparse. The main federal legislation which deals in some capacity with ICT and its energy usage is the 2007 "Energy and Security Act 2007" bill which set new regulations for Class A power supplies. A "Class A" charger is any charger which performs voltage conversion, i.e. for a laptop or for a cellular phone (US DOE, 2010). The bill sets new standards for active and standby modes - the active mode requires certain efficiency based on the rating of the power supply (how many watts output it produces). The standby requirement is similar to the voluntary 5 Star System discussed in the Self Regulation section. It mandates a maximum standby consumption of 500mW (or 0.5 watt) for all Class A power supplies.

Electronic Hazardous Waste

More than twenty individual states in the United States have legislation related to electronic waste and toxic substances. In California, for example, Electronic Waste Recycling Act (EWRA), passed in September of 2003 and amended by Senate Bill 50 established a program for consumers to return, recycle and ensure safe and environmentally sound disposal of video display devices. The return and safe disposal is funded by the consumer in the form of a fee which is paid upon purchase of the video display device.

Additionally the EWRA prescribes limits for the amount of toxic substances which can be contained in certain products sold in California. Under this law the Maximum Containment Values (MCVs) under California's RoHS law are the same as those that apply to the EU's RoHS Directive. For lead, mercury, and hexavalent chromium the MCV is 0.1% by weight. The MCV for cadmium is 0.01% by weight. Unfortunately, this legislation only affects California, so the rest of the states in the USA do not have to adhere or implement this legislation.

Energy Labeling Schemes

Energy labeling schemes are one of the most visible and widespread types of voluntary regulation in the ICT sector. Most every consumer ICT device which can be purchased has a reference to an environmental or energy consumption certification. Energy labeling schemes are voluntary, which means that manufacturers are not legally obliged to adhere to any of their standards, but manufacturers which voluntarily adhere to the standard have the added marketing benefit of being able to place the scheme's logo on their product. This logo may be perceived by the consumer as an advantage over a product which does not have the same logo.

Energy Star

Energy Star is an energy labeling scheme which started in 1992 in the United States of America. Energy Star is:

> A voluntary labeling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. Computers and monitors were the first labeled products. Through 1995, EPA expanded the label to additional office equipment products and residential heating and cooling equipment. In 1996, EPA partnered with the US Department of Energy for particular product categories. The ENERGY STAR label is now on major appliances, office equipment, lighting, home electronics, and more. EPA has also extended the label to cover new homes and commercial and industrial buildings.
>
> Source: ENERGY STAR, 2010.

Energy Star covers a wide variety of devices from home appliances like refrigerators, telephones, lighting, and office equipment to industrial applications such as HVAC (Heating Ventilation and Air Conditioning) units. The Energy Star program prescribes a reduction over standard usage based on data from prior years. For example the Energy Star 5.0 specification demands a 30% to 60% reduction in energy usage by computers depending on usage. Computers, servers, printers, scanners and other home / office electrical devices are covered by the Energy Star program.

Cellular phones are notably absent from the energy star program, only earning a mention in the Standby Power and Energy Vampires section where Energy Star recommends that charging devices be unplugged from the wall when no device is being charged.

IEEE 1680.1 and EPEAT

The ICT Regulation Toolkit (a joint production of infoDev and the International Telecommunications Union) addresses the issue of ICT and the environment in Module 4, Universal Access and Service. The ICT regulation toolkit suggests that ICT equipment should conform to the IEEE 1680.1 standard for the environmental performance of electronic equipment. The IEEE 1680.1 standard is one which takes a cradle to grave approach when rating products, including the production, use and disposal phases into the ranking criteria.

EPEAT is an organization / rating system which "implements IEEE 1680 standards by operating the Registry of conforming products and conducting verification. The role is spelled out in IEEE 1680 - the umbrella standard" (Rifer, 2010). EPEAT "helps purchasers evaluate, compare and select electronic products based on their environmental attributes. The system currently covers desktop and laptop computers, thin clients, workstations and computer monitors" (EPEAT, 2010).

EPEAT / ISO 1680.1 outlines eight different categories which manufacturers must comply to in order to receive a rating. There are three different ratings based on how many of the Optional Criteria that the product fulfils. The ratings are and corresponding requirements are:

Table 10: EPEAT Ratings

EPEAT Bronze	Meets all 23 required criteria.
EPEAT Silver	Meets all 23 required criteria plus at least 50% of the optional criteria.
EPEAT Gold	Meets all 23 required criteria plus at least 75% of the optional criteria.

There are eight different sections of criteria which are summarized in Table 11: EPEAT Required Criteria below. A full list of EPEAT criteria is provided in the appendices.

Table 11: EPEAT Required Criteria

Category	**Required by IEEE 1680.1**
Reduction / elimination of environmentally sensitive materials	• compliance with provisions of EU Restriction of Hazardous Substances Directive upon its effective date • Reporting on the amount of mercury used in light sources • Elimination of intentionally added SCCP flame retardants and plasticizers in certain applications

Materials selection	• Declaration of post consumer recycled plastic content • Declaration of renewable/bio-based plastic materials content • Declaration of product weight
Design for end of life	• Identification of materials with special handling needs • Elimination of paints or coatings that are not compatible with recycling or reuse • Easy disassembly of external enclosures • Marking of plastic components • Identification and removal of components containing hazardous materials • Minimum of 65% reusable/recyclable
Product longevity / life cycle extension	• Availability of additional three year warranty or service agreement • Can be upgraded with common tools
Energy conservation	• Energy Star Compliance
End of life management	• Provision of product take-back service • Provision of rechargeable battery take back service
Corporate performance	• Demonstration of corporate environmental policy consistent with ISO 14001 • Self-certified environmental management system for design and manufacturing organizations • Corporate report consistent with Performance Track or GRI
Packaging	• Reduction / elimination of intentionally added toxics in packaging • Separable packing materials • Declaration of recycled content

Source: IEEE Standard 1680.1, Section 4

The IEEE 1680.1 standard is more comprehensive in consideration of the entire lifecycle of ICT products. The wide range of criteria areas which must be fulfilled including the material selection, corporate responsibility, longevity / life cycle extension, and end of life management show the more comprehensive approach to environmental protection by the IEEE 1680.1 system under EPEAT as compared to an energy label such as Energy Star. This can be seen clearly by the fact that Energy Star is merely one of twenty-three required criteria.

Self Regulation

Industry self regulation is another form of regulation which needs to be taken into consideration when looking at regulation in the ICT industry. Industry self-regulation in some cases has more ambitious goals than state mandated regulation. An example of this is the Five Star System which is an industrial voluntary agreement which defines energy efficiency index for mobile phones. The no-load power consumption values can be found in Table 12: Five Star Ratings.

Table 12: Five Star Ratings

Scoring		**No-load Power Consumption**
Five Stars	<=	0.03 W
Four Stars	>	0.03 W to 0.15W
Three Stars	>	0.15 W to 0.25 W
Two Stars	>	0.25 W to 0.35 W
One Star	>	0.35 W to 0.5 W
No Stars	>	0.5 W

Source: Product Environmental Information Task Force Energy Efficiency Index for Mobile Phones

Chapter V

Analysis of ICT Energy Demand

"The real challenge is to address heavy energy consumers. ICT can help. It is indeed a typical anti-inflationary industry that with time gives you more for less. But the real problem is to cut heavy consumption,"

- Intel chairman Craig Barrett

Research and analysis of historical power consumption trends as well as Moore's law and its relationship with energy demand will be explored in this chapter.

Power Supply Trend Analysis

Although the sheer number of PCs which exist today is many orders bigger than at its inception, the power rating in terms of watts required of computer systems has not increased at the same rate which the performance and number of transistors has.

Moore's Law

"Nearly 40 years ago, Intel co-founder Gordon Moore forecasted the rapid pace of technology innovation. His prediction, popularly known as Moore’s Law, states that transistor density on integrated circuits doubles about every two years[26]" (Intel, 2005). The amount of transistors on the CPU also correlates to speed rating of the

[26] Moore's law is sometimes incorrectly cited as the performance per cost doubling every 18 months to 2 years. This statement is also true, but the performance increase is rather a side effect of technological innovation and steady manufacturing costs related to the manufacture of semiconductors.

processors of PCs in that an increased number of transistors will result in an increased processor speed[27]. Historically the number of transistors has increased in an exponential fashion as is displayed in Figure 4: Moore's Law. Moore's Law states that the number of transistors which can be inexpensively placed on an integrated circuit will roughly double every two years. In this hypothesis the size of the integrated circuit stays the same while the density per fixed area doubles. In the 1984 semiconductor based CPUs had roughly 240,000 transistors and according to Moore's law in 2010 the number of transistors is predicted to be around 1.97 trillion. The law can be said to be true up until now as some of Intel's new quad core processors have approximately 2 trillion transistors.

Moore's Law and Energy Usage

In Figure 5: Moore's Law and Wattage the transistor counts from Moore's Law are combined with data taken from Apple Macintosh computers since 1984 when the first commercially available Apple Macintosh computers hit the market for users who did not have the electrical engineering knowledge to build a computer from a kit[28]. This combination of data can be used to illustrate a few interesting points which are related to PCs and energy consumption. Firstly, as can be seen by the blue line which traces this history of the overall wattage required by the PC, wattage required by PCs has increased in a linear fashion, starting with these particular Macintosh Models at an average of 60 watts and increasing to an average of around 225 watts in 2009 (with some high performance models requiring up to 1400 watts).

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[27] It is important to note however, that the number of transistors and the processor speed do not directly correlate. In the example of Intel's Pentium M (Banias and Dothan) processors the number of transistors increased from approximately 77 Million with the earlier Banias processor to 140 million, an increase of 45% whereas the maximum processor speed only increased from 1.7GHz to 2.1 GHz, an increase of roughly 33% (Shimpi, 2004).

[28] The data concerning wattage was acquired by the generous cooperation of Glen Stanford (of http://www.apple-history.com/) and reflects the maximum wattage rating of the power supply when it was shipped with the computers. Data was averaged on a yearly basis and taken from all Apple Macintosh models from 1984 to 2010 where power supply wattage rating was available. Overall 230 Apple Macintosh models were used in the average. Aggregated data can be found in the appendices. While this dataset is admittedly small, it was chosen because of the availability of the data. The trend is generally applicable to all PCs – the maximum power supply rating wattage of a new computer will be between 300 and 500 watts, with actual usage being less.

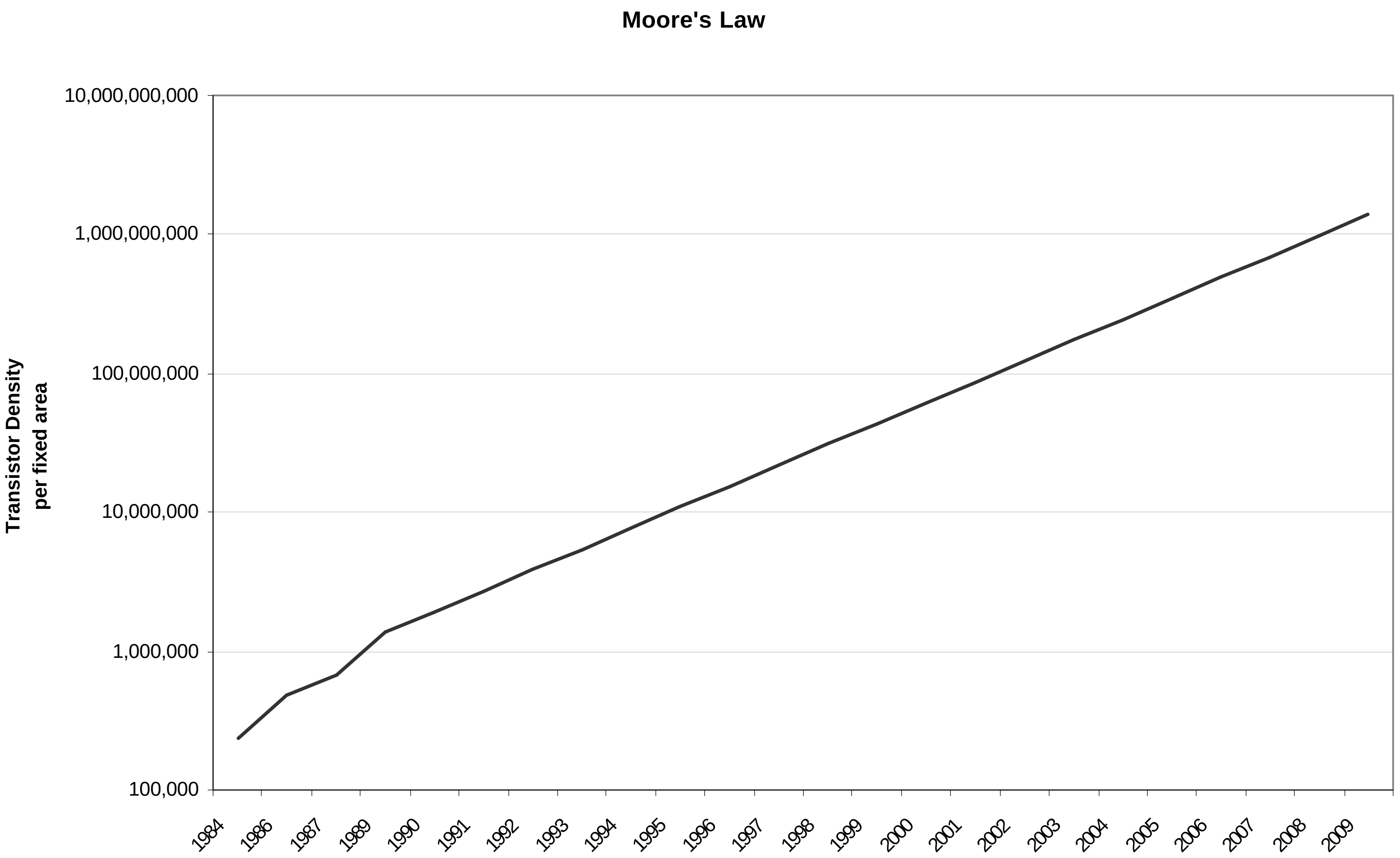

Figure 4: Moore's Law

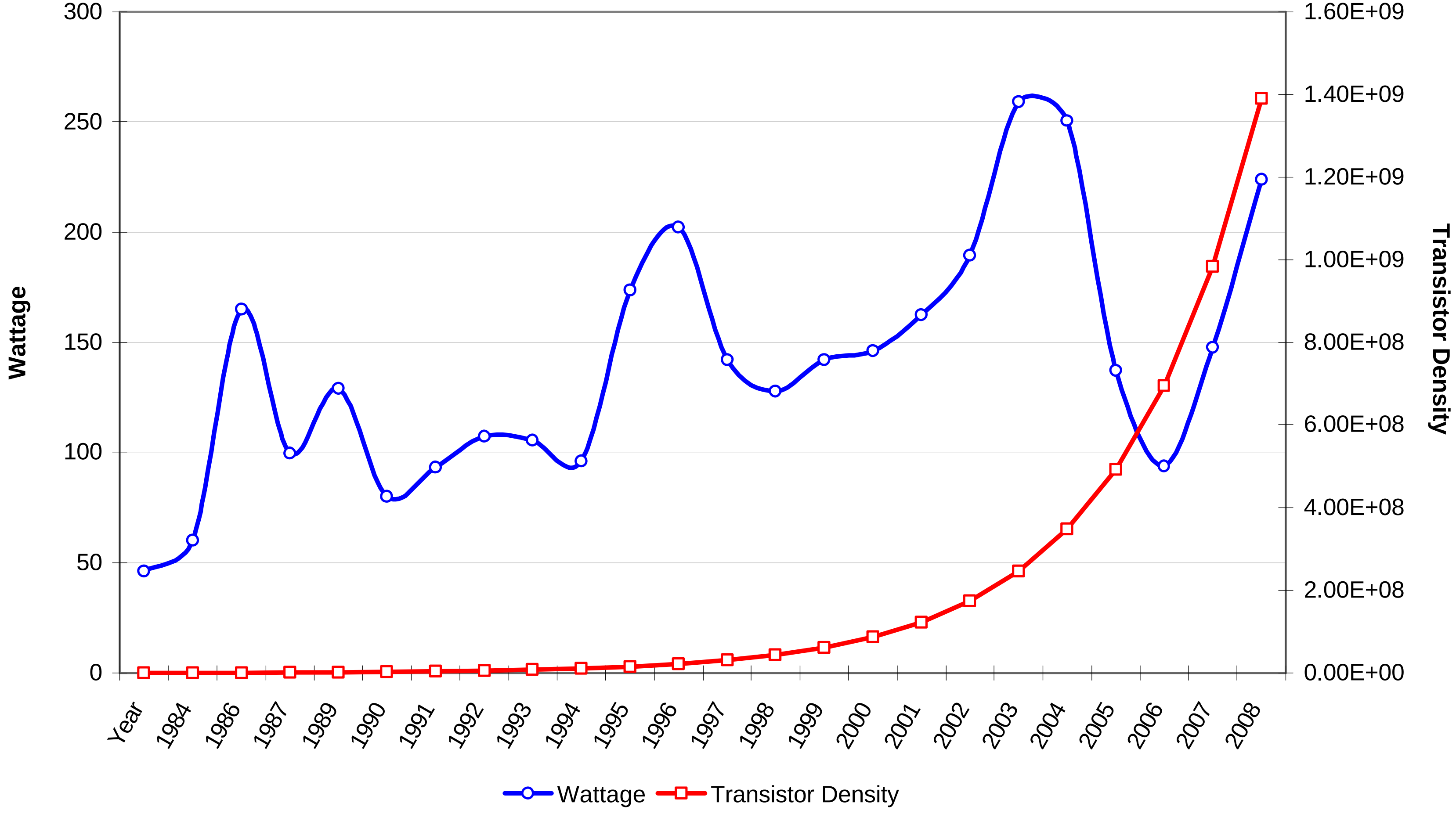

Figure 5: Moore's Law and Wattage

Analysis of Energy Usage and Moore's Law

What can be discerned from Figure 5: Moore's Law and Wattage is the historical correlation between power supply maximum wattage and the transistor count of computer microprocessors. What can be seen is that although the average energy demand has increased (in this case from around 50 watts in 1984 to 225 watts in 2008), the energy demand has increased on a linear scale as can be seen by following the blue plot which corresponds with the wattage scale on the left. The red plot can be examined in conjunction with the logarithmic scale on the right hand side of the graph which starts at 240,000 in 1984 and just shy of 1,400,000,000 in 2008.

As the density of the transistors on semiconductor computer chips increased so did the energy demand for these chips, but due to advances in technology and manufacturing processes the energy demand did not increase at the same rate as the transistor density did. In terms of sheer energy demand per semiconductor computing chip this correlation is a double edged sword. On the one hand, although energy demand has increased, it has not increased in an exponential fashion. On the other hand, technological advances and demand for cheap processing power increased the demand for semiconductor chips – and thus the energy consumed by all existing chips. While the energy usage did not increase per chip at the same rate as the performance, the sheer demand for processing power and semiconductor chips had a dramatic effect on the total energy demand for the PC and the ICT sector.

According to Gartner Dataquest's statistics, in April 2002 the billionth personal computer was shipped. The second billion mark was supposedly reached in 2007. But how many computers are actually in use? According to a report by Forrester Research, there will be over one billion PCs in use worldwide by the end of 2008. And with PC adoption in emerging markets growing fast, it is estimated that there will be more than two billion PCs in use by 2015, Forrester predicts. Therefore, whereas it took 27 years to reach the one billion mark, it will take only 7 to grow from 1 billion to 2 billion (IDC, 2010).

Chapter VI

Suggestions for ICT and Sustainability

> *It is easier to save energy if one can monitor the consumption as accurately and quickly as possible.*
>
> *EU Commission Working Group on the Smart Distribution Network*

This chapter serves as a synthesis of the information presented in the previous chapters regarding ICT and their relationship to energy consumption, sustainability, and the environment. Current trends in the ICT sector as well as in the application ICT will be critically examined.

Combating Planned Obsolescence

If ICT is to become a driving force in sustainability it needs to be viewed with less of a consumerist "throw away" mentality. Planned obsolescence turns ICT products into consumer durables to be used for a short period of time and then disposed of. However, unlike other consumer goods, the end of life of ICT devices is potentially much more dangerous than a less complex product. As Simon Forge observes, "design for disposal encourages throwing away ever more sophisticated and energy-expensive items" (Forge, 2007). Forge points to the ever shorter model cycle of ICT which is a "questionable strategy in environmental terms" – for example one ICT vendor does not hold parts for bubble jet printers which cost less than $250, making the repair of such devices impossible. This section will illustrate ways in which manufacturers as well as public entities can help.

End to Moore's Law

ICT manufacturers must not continue to use Moore's Law as a mantra to continually push the limits of technology only to increase capacity and performance – consideration must be put on the side-effects. Development must be encouraged to continue in an environmentally sound manner. For example, increasing the processing speed two fold whilst consuming four times more energy and resource input during manufacturing must be no longer feasible either through economic or regulatory means.

For example, a recent strategy for chip manufacturers was to put more and more transistors onto chips even if they cannot fit them into the same space as before – in effect only by layering them or making the processors bigger. This strategy is not environmentally sound using current technologies given that as the size increases so does the energy consumption of the transistors. If ICT and development in the future is meant to be sustainable it is not reasonable to simply increase the processing power of computers by simply expending more energy in its manufacture and operation. Design emphasis must be put upon reducing the energy requirement or at using the energy in a more efficient fashion.

Data Centers

Data centers hold a large potential for reducing energy usage. As was shown in a study by Blazek et al. in 2004 simply by changing the way that power for lighting, heating, and cooling is used within the facilities the energy required for data centers can be reduced. Although in their study the computer room floor area, computer systems, and computing power of the facility was increased the energy usage per square meter stayed constant. If data centers were able to allow servers to go into light sleep or sleep (standby) mode as indicated by the figures in Table 7: Data Center Power Density on page 10 the energy savings potential for data centers would be enormous.

Behavioral Changes

Technological advances and prowess alone will not be enough to solve the problem of the environmental of impact of high technology. As is clearly illustrated by the rebound effect efficiency measures simply cause our society to exact a higher and higher toll upon our planet in the form of energy consumption. Global population will continue to grow in the coming decades and if this population growth is not decoupled from energy usage per capita the population will exact possibly irrecoverable damage to our planet. In order to achieve a sustainable global society a decrease in the energy consuming behavior is required.

Information and Communications Technologies have the advantage that they enable the collection and analysis of data which may otherwise go unnoticed. ICT can be employed in many passive forms – such as in smart building management systems or energy management systems which allow for the collection, analysis of energy consumption data. This very important data can then be processed either automatically processed by such systems or used in reporting and analysis to try to affect energy consumption behavior. This concept is aimed at providing users with more information about there energy usage, allowing them to change their energy consumption behavior. An example of this is the Flower Lamp from Sweden which "blooms" by changing its shape when energy consumption has been low for an extended period of time (Loveday et al., 2008).

Figure 6: Flower Lamp (Interactive Institute 2005)

Avoiding the Rebound Effect

Energy efficiency will result a short term improvement in energy consumption when it is implemented, but it is also important to examine the long term implications of the gain in efficiency. The rebound effect is one very good reason why it is important to consider the longer term implications of higher efficiency. Higher efficiency usually results in a lower price for a commodity or good, as in the example of electrical power – the power generation process becomes more efficient which means the distributor can charge a lower price for electricity. Another example is the increase in usage of hybrid automobiles – more efficient fuel usage could result in more overall fuel consumption as drivers tend to drive more. Increased consumption is of course not always the case, but as has been proven in the case of energy consumption and it is certainly true that ICT has experienced the rebound extent to some extent. As Herring and Roy observe in their paper "energy efficiency may not be as 'environmentally friendly' as many claim and its promotion will not necessarily lead to a reduction in energy consumption and thus carbon emissions" (Herring and Roy, 2007).

In the economy as a whole ICT has been attributed to a great increase in productivity. In the ICT sector the rebound effect is also apparent, being attributed to phenomena such Moore's Law by some (Plepys, 2002). Regardless of its root cause the rebound effect is a reality in the ICT sector – as the capability goes up and the price goes down (or stays stable in some cases). The effectiveness of ICT in making many processes in all sectors of the economy easier and more economic resulted in it being put on a pedestal in the minds of many including investors. As Plepys points out this created a positive feedback loop – the growing expectations from ICT resulted in more investment into the sector. This increase in funds resulted in more investments in R&D which then resulted in rapid technology innovation, improvements in ICT products, and completing the loop with even higher expectations (Plepys, 2002).

Unfortunately, unless (or until) environmental costs are internalized into the market, using a price mechanism, it becomes necessary to have policy intervention. As can be seen in the in the earlier chapter on Legislation Affecting the ICT Sector, the example of Waste Electrical and Electronic Equipment and IEEE 1680.1 and EPEAT legislation which begins regulate ICT using a cradle to grave approach. This trend needs to continue to try to mitigate the effects of the rebound effect in ICT before it passes a point of no return.

The Enabling Effect

In the energy industry, information is power. ICT, simply by virtue of being an information enabler, can help to disseminate this information. Studies have shown that advanced technologies enable consumers to be active participants in improving grid efficiency and reliability. In a joint test project between U.S. Pacific Northwest National Laboratory and regional utilities power use was reduced 15% during peak hours simply by providing energy consumers with more information about the energy they were consuming. The same energy users saw approximately a 10% reduction in their energy bill (Smart Distribution Network Working Group, 2009).

This effect which can be attributed to ICT is the so called "enabling effect". This refers to the role which ICT can play in tracking, analyzing, and helping to reduce energy usage in other sectors such as manufacturing, transport, buildings, and power generation. As was mentioned in ICT and Energy Usage, in some instances the mere usage of ICT has the side effect of reducing energy consumption in other sectors. Despite the fact that the demand for and number of ICT devices and its energy demand will continue to rise in the near future, this does not paint completely dire picture for environmental sustainability. The energy demand for ICT will rise along with the increase in demand for the ICT itself, but with planning and regulation it will be possible to employ the ICT in other sectors to monitor total energy consumption and overcome the rebound effect.

The opportunity, as outlined in the Smart 2020 report, consists of applying ICT in a manner in which current everyday practices which are energy consuming can be shifted into immaterial goods. Examples include online billing, electronic media and music which replace paper and CDs with a less energy intensive virtual good. All of these examples reduce emissions and energy needed for the manufacture and distribution of the products (The Climate Group, 2008). Replacing material with virtual goods is not the only way in which ICT enables energy savings. The concept of smart electricity grids, logistics, and buildings also affords opportunities to reduce energy consumption through the intelligent use of ICT.

Smart Electricity Grids

Energy efficiency and smarter use of available energy can be achieved in many ways. Until now the focus has been on the end of the line devices, as in the example of higher efficiency light bulbs or computers which use less energy or shut themselves down after a period of time. But, the energy distribution network itself is a candidate for improvement and the intelligent use of information on a grid wide basis would bring considerable energy savings.

Today's power grid is largely unidirectional and passive, meaning that the electricity flows from the power source (power plants) through the transmission grid to the distribution network where it is then distributed to the customer demanding the electricity. The grids in the U.S. as well as Europe decades old will need to be replaced soon. The current state of the power grid is such that there is very little to no bidirectional communication from the load demanding customers back through the distribution and transmission grid.

ICT can be employed in the current electricity distribution system which is ageing and needs to be monitored. DONG energy, a Danish energy supplier, implemented such a solution in 2007. The projected benefits were a 25-50% reduction in Non Delivered Energy, a 35% reduction in time searching for faults in the grid, and up to a 90% reduction in network reinforcement costs (Smart Distribution Network Working Group, 2009).

Smart Metering

Measuring electricity at the point of use has not changed drastically for the last 75 years. It has not changed because there was neither demand, nor financial justification for meters which could measure more than just the flow of electricity. Smart meters with a time-trend analysis of energy usage were prohibitively expensive to implement on a wide scale because the value gain was negligible for most customers. The gain would be primarily realized by larger customers who could react to and benefit from the complex rates and frequent price changes (Neenan and Hemphill, 2008). However, if ICT could be employed to perform this same task – of tracking and responding to price changes in the system – a wider base of energy consuming customers could also enjoy the benefit of varying energy prices. For example if one had a hybrid vehicle which required electricity to charge, it could be connected to the grid and then only draw electricity when the price was below a certain level. On the other hand, with ICT and a smart grid system this same car could supply energy to the grid if electricity price was high enough.

A possible long term benefit is that ICT could help to change the behavioral patterns of consumers, effecting the ‘Third-order’ or ‘tertiary’ medium- or long-term adaptation of behavior (consumption patterns) and economic structures (Hilty, 2008).

Smart Logistics

Freight transport has been has been on the rise in recent history, not in small part due to the e-commerce trend and more generally due to upturn in economic activity.

ICT has been one of the biggest enablers for e-commerce and e-commerce results directly in more transportation of goods using energy intensive transport methods. Unfortunately the transport operation in and of itself is inherently quite inefficient – requiring packaging, transport, and storage for many goods. Also as fuel prices and taxes rise it has become a priority to promote and establish more efficient methods of transport. For example wasted energy by a truck which carries little or nothing on a return journey can be avoided with a little bit of planning and intelligent use of ICT for coordination (The Climate Group, 2008).

As freight transport is generally coupled with GDP it is not expected to decrease in coming years without either behavioral changes or external pressure in the form of increased costs of transport. For this reason the largest potential for savings of energy from freight transport is results from virtual goods and the dematerialization of the economy. While the so called Intelligent Transport Systems achieved by ICT employment in the transport sector will make transport efficient and likely result in a rebound effect if there are not any other factors involved (Erdmann et al., 2004).

In order to achieve tangible energy savings in the logistics sector a decoupling of transport demand with economic growth must occur. Such a decoupling could be achieved by an increase in the price of energy and fuel prices, which are unavoidable costs in the transport sector. Additionally there must be external motivation to reduce the amount of transport – for example as suggested by Erdmann et al. to include the carbon emissions from the transport industry in carbon trading schemes – in effect internalizing the environmental externalities of the transportation. This inclusion would serve as encouragement to reduce the demand for transport.

Smart Buildings

Facility heating represents the largest energy consumer for buildings, being estimated at 39% of the initial value of total energy consumption of the building and up to 59% of yearly energy consumption[29], in colder climates it makes up the bulk of the energy which is consumed by buildings. ICT can be used in facility management

[29] The 2008 article from Loveday et al, 2008 cites 59% of total energy per year for buildings in the U.K., while Erdmann et al., 2004 look at the whole life energy use with 39% of the initial energy expenditure being consumed during the building's lifetime.

in order to realize savings resulting from improved heat management. Facility management with the support of ICT has considerable potential to reduce future energy consumption. The rebound effect must also be considered as increases in energy efficiency have tendency to promote higher usage (Erdmann et al., 2004). These effects could be mitigated by encouraging behavioral changes through public awareness campaigns as well as through financial means by including the negative environmental externalities to some extent into the price of the energy which is used. Such a tax could be dependent on the property zoning (residential versus commercial) and energy usage as compared to the total area which is to be heated. This tax could then be then used for example, to fund public awareness campaigns to promote more sustainable energy consumption patterns.

Using ICT to monitor ICT

There is a need to start collecting statistics on ICT and its effect on and contribution to the waste stream. ICT itself is a contributor to the waste stream, and if the increase in consumption tied to the rebound effect continues, ICT will become in and of itself a larger part of the problem. ICT, unlike conventional waste, presents a host of other problems associated with the disposal, recovery, or safe storage of toxic and or scarce elements contained in it. As the OECD points out in its report on the relationship between ICT and the Environment there is a lack of official statistics on e-waste, with two programs in Canada and Australia being the exceptions (OECD, 2009). For example, a Canadian survey attempted to find out what households did with ICTs ("Unwanted computers or communications devices"). The categories were "Put into the garbage", "Still had them in 2005 and did not know what to do with them", "Returned to supplier" and "Donated or gave away" (Statistics Canada, 2006). More reporting such as this is vital in accessing the impact which ICT will have in the long run on the environment.

Government Behavior

Another often overlooked factor which can greatly affect efficiency is government and not only indirectly through legislation, but also directly as the government's presence as a consumer. In 1993 President Clinton signed an executive order (EO 12845) which required that the US Government to purchase Energy Star PCs, monitors and printers. This executive order had a significant effect on the number of products on the market which carried the Energy Star label (Koomey et al., 1996).

Chapter VII

Summary and Conclusions

All enduring societies—human or animal—have had to achieve a tolerable balance between their population and their supporting environment, including resources.

Vance Packard, The Waste Makers,, 1960

The impact which ICT will have on society and the planet in the coming decades is far from certain and is a topic of debate in all sectors, from government to private industry to international regulatory bodies. It is certain however that ICT has become inseparably intertwined with western society in the last three decades. The surge of ICT has affected modern day life and economies in a significant way. It has optimized processes, helped to reduce waste in terms of unsold product by optimizing supply chain management, created online marketplaces which did not exist before, to mention a few examples. The growth of the ICT sector itself as a consumer durable good is also on the upturn in recent decades. This upturn has been caused by the market demanding better, faster, cheaper goods.

The role of (and energy demand of) ICT has increased as a percent of the total share of energy consumption. At its inception ICT lacked almost any regulation, but this has changed over the years. As ICT became more technologically advanced and more widespread it began to increasingly come under regulatory scrutiny. Governments and regulatory bodies increasingly recognize what kind of threat ICT can pose to the environment if not regulated. Important steps have been taken to regulate the damage that ICT inflicts upon the environment. Additionally, its manufacture and distribution is increasingly considered in a lifetime, cradle to grave approach – that is from the raw materials which go into the product, the lifetime impact of the product, as well as the end of life disposal.

Until recently ICT was not seen, in and of itself, as a significant factor in overall energy and resource consumption. Advances in technology allowed for more processing power to be achieved without drastically increasing the size of the technology, and indeed in most instances the result was smaller technology. These advances also helped make ICT cheaper resulting in higher numbers of devices in the world – increasing the overall energy demand. Technological advance also results in more complicated devices which require more physical resources, all of which must be attained from the environment. This attainment exacts a higher toll on the environment. But as analyses have shown, the impact is not small, and quite to the contrary it is one which has become significant and a problem must be addressed.

ICT has become more and more energy efficient in the past decade – this increase in efficiency being attributable to government regulation as well as manufacturer initiative. Regulation related to power consumption has begun to become more and more common place, and a consistent improvement in energy efficiency is of utmost importance. Unfortunately, as the rebound effect in the energy industry first showed, this efficiency was not something which necessarily reduced the impact of ICT. On the contrary, in many instances it caused older, more inefficient devices to be replaced by an increased number of energy efficient and cheaper devices. The problem of disposal began to come to the forefront – for example with older CRT monitors being replaced by LCD technologies. The saturation rate of ICT has also increased in the last decade, and consumer behavior and purchasing patterns seem to indicate that there will be a consistently increasing demand for ICT into the foreseeable future, thus it is reasonable to suppose that the problems associated with them will not diminish in the near future.

Now that sustainability has become an increasingly important theme in the public as well as private sphere the question of what role ICT plays in this development has arisen. Until now there has not been an emphasis in employing ICT in a fashion which attempts to specifically promote and support sustainable development. As mentioned earlier, it has already been used to reduce unnecessary waste in business and market processes, but until now the cost savings have either been passed on to the consumer or retained by the companies in the form of profit. In order for ICT to play a key role in sustainable development it must be employed in a fashion which does not encourage more consumption, but rather in one which encourages smarter, more sustainable consumption patterns.

Transportation, building, energy generation and distribution, logistics and many other sectors in the consumer market stand to profit from the smarter use of ICT. Smart electricity grids can be built to facilitate two way communications – from the energy consumer back to the producer, buildings can be made more energy efficient by automatically controlling services such as heating and cooling, logistics can be run in a more efficient manner, and physical products such as books, movies, or music can be digitized – removing the demand for the physical product.

However, ICT is not a silver bullet; it can not be expected to solve the problem alone. In the information society which we live today ICT can be used to help effect behavioral change which is necessary for sustainable development. The observation and systematic analysis of data related to climate change, energy usage, and other pertinent issues can be facilitated and improved upon.

Human activity has an impact on our environment and the planet and this impact is an important one. As the population grows and lifestyles change it is important to place emphasis on the ramifications which these changes will have on the planet. In the future it is unavoidable that human kind must think and act in a fashion which considers the long term.

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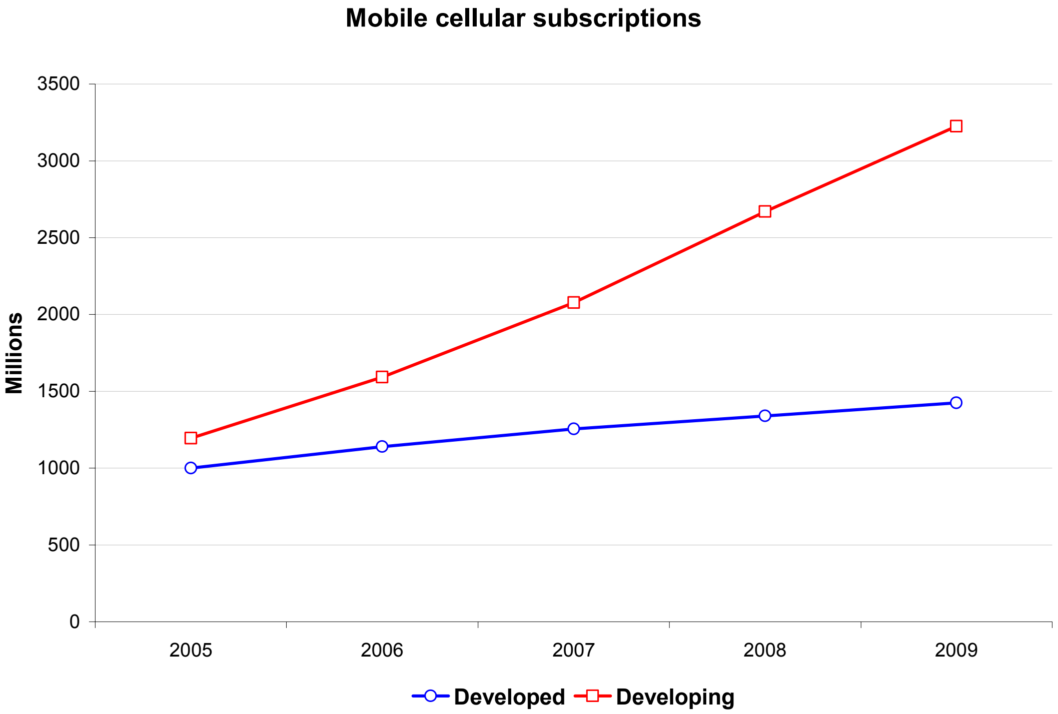
Key Global Telecom Indicators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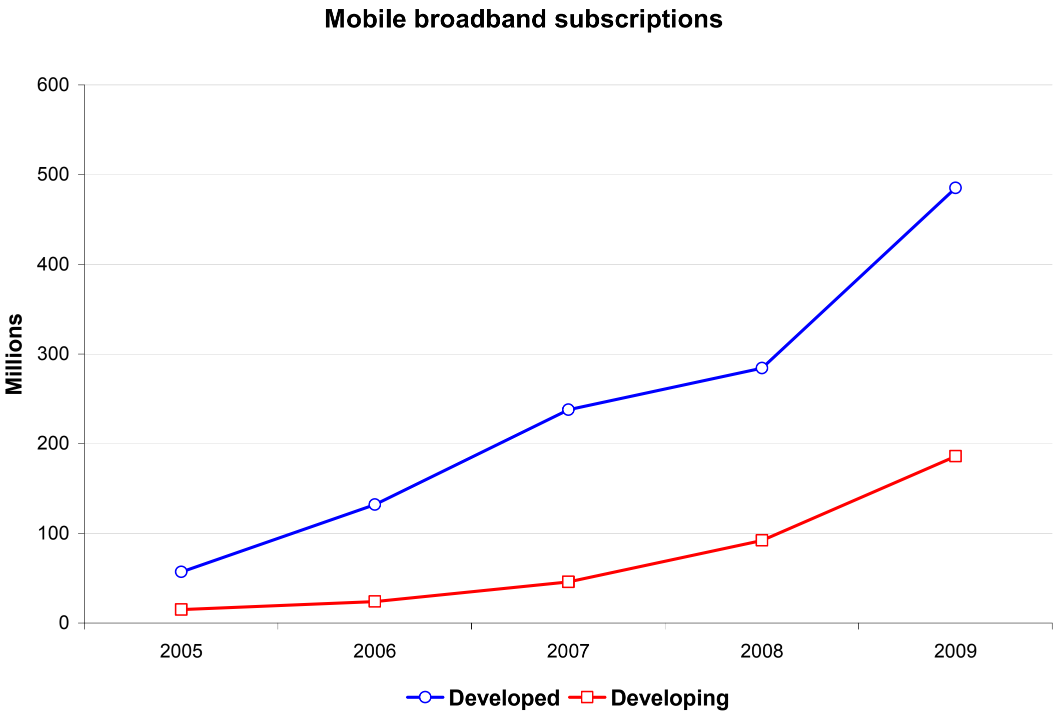
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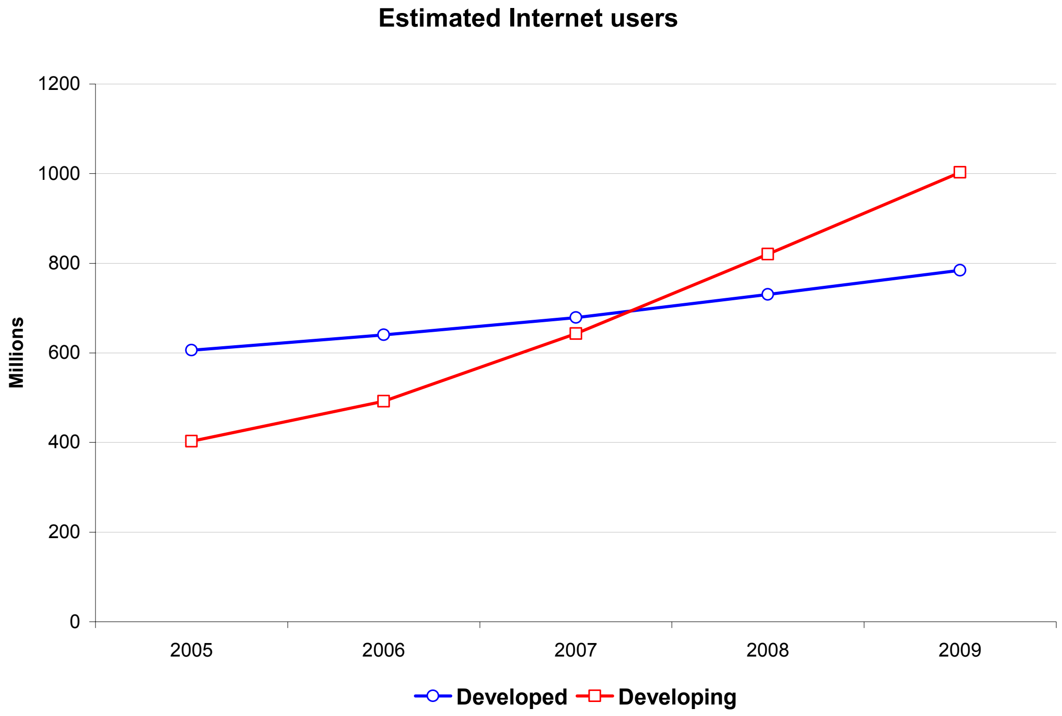

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Millions
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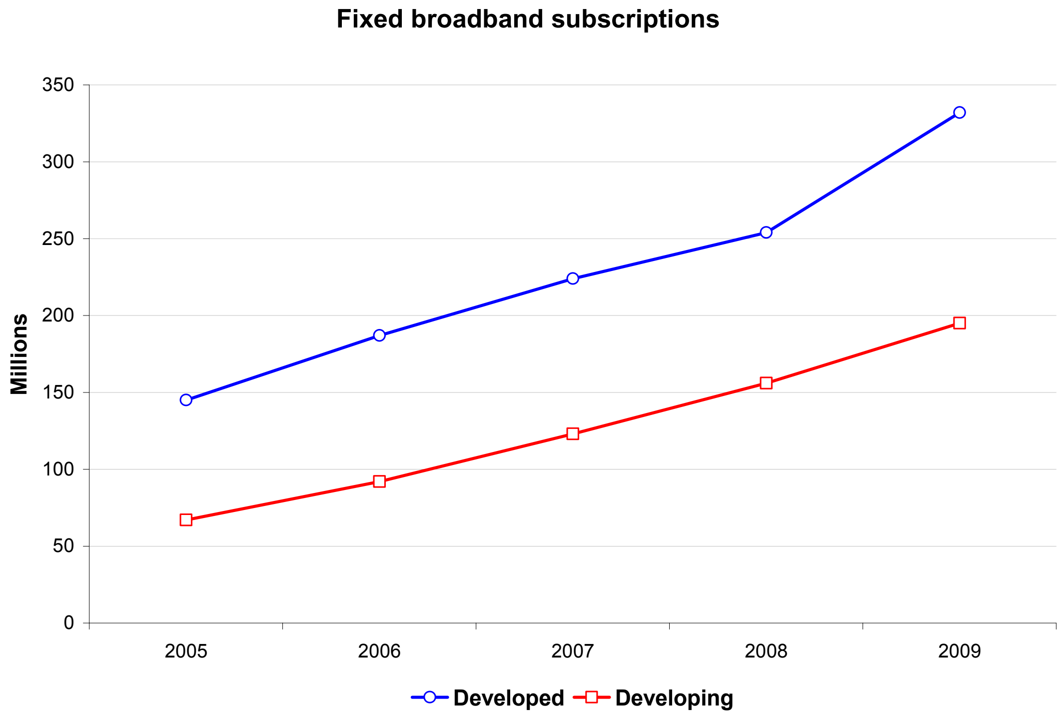
2006
2007
2008
2009
Developed
Developing



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350
300
250
200
150
100
50
0
Millions
2005
2006
2007
2008
2009
Developed
Developing

IEEE 1680.1 and EPEAT

IEEE Standard 1680.1

Section 4
Environmental performance criteria

for desktop personal computers, notebook personal computers and personal computer displays

This document paraphrases the environmental criteria included in IEEE Standard 1680.1, which includes the requirements for computers and displays. 1680.1 is part of the IEEE 1680 family of standards. IEEE Standard 1680 includes specifications for how the system is intended to work. This document summarizes the contents of the 1680.1 standard but does not provide all the information needed by a manufacturer to determine if their product is in conformance nor to declare its conformance with the Standard.

Regional variability: Certain criteria can allow for different declarations in different regions or countries, based on the Registry listing of regions and countries. These regionally variable criteria are identified below. Unless otherwise noted, the declared criteria must be met by all units of the product as they are sold anywhere in the world.

Copies of the full IEEE Standard 1680 or IEEE Standard 1680.1 can be purchased from IEEE at <http://shop.ieee.org/ieeestore>. Simply search for the standard number.

Note: **Required criteria** have the criteria number in bold for ease of reference.

4.1 Reduction/elimination of environmentally sensitive materials

4.1.1 Reduction of use of hazardous substances

4.1.1.1 Compliance with provisions of European RoHS Directive

A required product criterion

All covered products shall comply with the requirements of the European RoHS Directive 2002/95/EC for the restriction on certain hazardous substances in electronic equipment. The Directive addresses cadmium, mercury, lead, hexavalent chromium, and certain brominated flame retardants. For details reference the European RoHS Directive.

4.1.2 Cadmium

4.1.2.1 Elimination of intentionally added cadmium

An optional product criterion

All covered products shall have concentrations of cadmium less than half the threshold defined in RoHS, unless the presence of cadmium can be shown to be due to use of recycled content.

4.1.3 Mercury

4.1.3.1 Reporting on amount of mercury used in light sources

A required product criterion

For all flat panel video display devices manufacturers shall report on the amount of mercury used in light sources in all covered products.

4.1.3.2 Low threshold for amount of mercury used in light sources

An optional product criterion

All flat panel video display devices shall employ lamps that contain a reduced amount of mercury relative to the current industry standard.

4.1.3.3 Elimination of intentionally added mercury used in light sources

An optional product criterion

All flat panel video display devices shall employ lamps that utilize a technology that does not the presence of mercury.

4.1.4 Lead

4.1.4.1 Elimination of intentionally added lead in certain applications

An optional product criterion

Video display units shall have concentrations of lead less than 5 percent of the threshold defined in the RoHS Directive per listed part, unless the presence of lead can be shown to be due to use of recycled content.

4.1.5 Hexavalent chromium

4.1.5.1 Elimination of intentionally added hexavalent chromium

An optional product criterion

All covered products shall have concentrations of hexavalent chromium that are less than half the threshold defined in the RoHS Directive, unless the presence of hexavalent chromium can be shown to be due to use of recycled content.

4.1.6 Flame retardants and plasticizers

4.1.6.1 Elimination of intentionally added Short Chain Chlorinated Paraffin (SCCP) flame retardants and plasticizers in certain applications

A required product criterion

All covered products shall contain no more than a trace amount of SCCPs in paints, coatings, plastics, rubbers or seals, unless the presence of SCCPs can be shown to be due to use of recycled content.

4.1.6.2 Large plastic parts free of certain flame retardants classified under European Directive 67/548/EEC

An optional product criterion

In all covered products the plastic parts larger than 25 grams shall contain no more than a trace amount of the flame retardants classified as dangerous substances under the European Directive on the classification, packaging and labeling of dangerous substances. For details reference the European Directive.

4.1.7 Batteries

4.1.7.1 Batteries free of lead, cadmium and mercury

An optional product criterion

In all covered products batteries and accumulators (internal to computer) shall not contain lead, cadmium and mercury over trace amounts. For applicable limiting values reference the European Directive 2006/66/EC on batteries and accumulators containing certain dangerous substances.

4.1.8 Polyvinyl chloride and chlorinated plastics

4.1.8.1 Large plastic parts free of polyvinyl chloride

An optional product criterion

In all covered products, except cables and interconnect parts, parts greater than 25 grams shall not contain polyvinyl chloride (PVC).

4.2 Materials selection

4.2.1 Total recycled plastics content

4.2.1.1 Declaration of postconsumer recycled plastic content

A required product criterion

For all covered products that contain plastics, manufacturers shall declare the percentage of postconsumer recycled plastic, excepting for printed circuit boards and packaging.

4.2.1.2 Minimum content of postconsumer recycled plastic

An optional product criterion

All covered products that contain plastic shall include an average of at least 10 percent postconsumer recycled plastic, excepting printed circuit boards.

4.2.1.3 Higher content of postconsumer recycled plastic

An optional product criterion

All covered products that contain plastic, except printed circuit boards, shall contain an average of at least 25 percent postconsumer recycled plastic.

4.2.2 Renewable/biobased plastic materials

4.2.2.1 Declaration of renewable/biobased plastic materials content

A required product criterion

For all plastic parts, except packaging, manufacturer shall declare percentage of renewable/biobased plastic materials.

4.2.2.2 Minimum content of renewable/biobased plastic material

An optional product criterion

All plastic parts, except packaging, shall contain an average of at least 10 percent renewable or biobased plastic.

4.2.3 Dematerialization

4.2.3.1 Declaration of product weight

A required product criterion

For all covered products, except packaging, manufacturer shall declare the product weight.

4.3 Design for end of life

4.3.1 Design for recovery through recycling systems that utilize shredding

4.3.1.1 Identification of materials with special handling needs

A required product criterion

For all covered products manufacturer shall provide treatment information to reuse and recycling facilities that identifies materials with special handling needs. This requirement addresses non-standard or new substances and technologies that would not be expected to be well-known to reuse and recycling operators.

4.3.1.2 Elimination of paints or coatings that are not compatible with recycling or reuse

A required product criterion

All covered products shall not contain paints and coatings on larger plastic parts that are not compatible with recycling and reuse. The technical requirements for compatibility with recycling have been defined by the Federal Electronics Challenge Plastics Task Force.

4.3.1.3 Easy disassembly of external enclosure

A required product criterion

All covered products shall have enclosures that are easily removable.

4.3.1.4 Marking of plastic components

A required product criterion

All larger plastic components shall be marked with a resin identification code according to the international (ISO) standard.

4.3.1.5 Identification and removal of components containing hazardous materials

A required product criterion

All covered products shall have larger circuit boards, and other components that contain hazardous materials, safely and easily identifiable and removable. The removal of materials and components is consistent with the requirements of the European WEEE Directive 2002/96/EC on electronic waste management.

4.3.1.6 Reduced number of plastic material types

An optional product criterion

The enclosures for all covered products shall have all the larger parts composed of only one type of plastic.

4.3.1.7 Molded/glued in metal eliminated or removable

An optional product criterion

All covered products shall not contain molded-in or glued-in metal inserts in plastic enclosures unless they are easy to remove.

4.3.1.8 Minimum 65 percent reusable/recyclable

A required product criterion

All covered products shall have at least 65 percent of the materials in the product reusable or recyclable using current infrastructure and technologies. Consistent with the European WEEE Directive 2002/96/EC on electronic waste management, component reuse is counted toward the percentage but not full product reuse.

4.3.1.9 Minimum 90 percent reusable/recyclable

An optional product criterion

All covered products shall have at least 90 percent of the materials in the product reusable or recyclable using current infrastructure and technologies. Consistent with the European WEEE Directive 2002/96/EC on electronic waste management, component reuse is counted toward the percentage but not full product reuse.

4.3.2 Design for recovery through disassembly

4.3.2.1 Manual separation of plastics

An optional product criterion

All covered products shall have the plastic parts, except very small ones, easily separable.

4.3.2.2 Marking of plastics

An optional product criterion

All covered products shall have the plastic components, except very small ones, marked with a resin identification code according to the international (ISO) standard.

4.4 Product longevity / life cycle extension

4.4.1 Manufacturer warranty/service agreement

4.4.1.1 Availability of additional three year warranty or service agreement

A required product criterion

All covered products shall have an additional three year warranty or service agreement available for purchase.

4.4.2 Upgradeability

4.4.2.1 Upgradeable with common tools

A required product criterion

All desktop and notebook personal computers shall be upgradeable with common tools, including memory drives, chips and cards that can be changed or extended.

4.4.2.2 Modular design

An optional product criterion

All desktop and notebook personal computers shall have a modular design such that major components and processor can be changed.

4.4.3 Product life extension

4.4.3.1 Availability of replacement parts

An optional product criterion

Spare or replacement parts shall be available for five years as well as information on how to obtain the parts

4.5 Energy conservation

4.5.1 Power management system

4.5.1.1 ENERGY STAR®

A required product criterion

All covered products shall comply with the version of U.S. ENERGY STAR that is applicable at the time of declaration.

4.5.1.2 Early adoption of new ENERGY STAR specification

An optional product criterion

All covered products shall be qualified to ENERGY STAR, or in compliance with the ENERGY STAR specification in advance of its effective date. This early adopter point, limited to one for a product, will be retained after the ENERGY STAR specification becomes required under criterion 4.5.1.1.

4.5.2 Use of renewable energy

4.5.2.1 Renewable energy accessory available

An optional product criterion

All covered products shall have a commercially available accessory for powering the product that uses renewable energy.

Regional variability: This criterion may be declared to differently for different regions or countries.

4.5.2.2 Renewable energy accessory standard

An optional product criterion

All covered products shall be shipped with a standard component for powering the product that allows for the use of renewable energy.

Regional variability: This criterion may be declared to differently for different regions or countries.

4.6 End of life management

4.6.1 Product take-back

4.6.1.1 Provision of product take-back service

A required annual corporate declaration criterion

The marketing and sale to institutions of all covered products shall include the option to purchase, at a competitive price, a take-back or recycling service that meets the U.S. EPA environmental standard defined in the “Plug-In to eCycling Guidelines for Materials Management,” published May 2004.

Regional variability: This criterion applies only in those regions or countries for which the product is declared as conformant with the standard.

4.6.1.2 Auditing of recycling services

An optional annual corporate declaration criterion

The marketing and sale to institutions of all covered products shall include an annual audit, according to the “Plug-In to eCycling Guidelines,” of all first, second and third tier recycling facilities that are used to provide the services required in criterion 4.6.1.1.

Regional variability: This criterion may be declared to differently for different regions or countries.

4.6.2 Rechargeable battery recycling

4.6.2.1 Provision of a rechargeable battery take-back service

A required annual corporate declaration criterion

The marketing and sale to institutions of all covered products shall include the option to purchase, at a competitive price, a rechargeable, lithium-ion battery take-back service that is equivalent to or better than that provided by the Rechargeable Battery Recycling Corporation (RBRC). Participating as a Licensee in RBRC in the U.S. and Canada qualifies for this criterion.

Regional variability: Manufacturer shall declare how they provide the service and may declare that they provide it by different means in different regions or countries. This criterion applies only in those regions or countries for which the product is declared as conformant with the standard.

4.7 Corporate performance

4.7.1 Corporate environmental policy

4.7.1.1 Demonstration of corporate environmental policy consistent with ISO 14001

A required annual corporate declaration criterion

All manufacturers shall demonstrate the existence and public availability of a written corporate environmental policy consistent with ISO 14001.

4.7.2 Environmental management system

4.7.2.1 Self-certified environmental management system for design and manufacturing facilities

A required annual corporate declaration criterion

All manufacturers shall self-certify that their owned organizations engaged in the design or manufacture of the product have an operational environmental management system that meets one of three recognized systems: ISO 14001, European EMAS or U.S. EPA Performance Track.

4.7.2.2 Third-party certified environmental management system for design and manufacturing facilities

An optional annual corporate declaration criterion

All manufacturers shall certify that their owned organizations engaged in the design or manufacture of the product have an operational, third-party certified, environmental management system that meets one of three recognized systems: ISO 14001, European EMAS or U.S. EPA Performance Track.

4.7.3 Corporate Reporting

4.7.3.1 Corporate report consistent with Performance Track or Global Reporting Initiative

A required annual corporate declaration criterion

All manufacturers shall produce an annual report that meets the first three reporting requirements of the U.S. EPA Performance Track or the Global Reporting Initiative (GRI) Sustainability Reporting Guidelines (2002).

4.7.3.2 Corporate report based on Global Reporting Initiative (GRI)

An optional annual corporate declaration criterion

All manufacturers shall produce an annual public report that is based on the Global Reporting Initiative (GRI) Sustainability Reporting Guidelines.

4.8 Packaging

4.8.1 Toxics in packaging

4.8.1.1 Reduction/elimination of intentionally added toxics in packaging

A required product criterion

Heavy metals shall not be intentionally added to any packaging or packaging component, with an exception for the use recycled content.

4.8.2 Recyclable packaging materials

4.8.2.1 Separable packing materials

A required product criterion

The packaging of products shall have all non-reusable packaging components larger than 25 grams separable into like materials without using tools.

4.8.2.2 Packaging 90 percent recyclable and plastics labeled

An optional product criterion

The packaging of products shall have the plastics identified by material type, and 90 percent of the packaging shall be materials that are readily recyclable (with available recycling options), or can be composted, or can be disposed of in a municipal sewage program. Labeling requirement does not apply to small plastic parts.

4.8.3 Recycled Content

4.8.3.1 Declaration of recycled content

A required product criterion

The manufacturer shall declare whether packaging contains recycled content, or does not, and shall declare the approximate recycled content for each material.

Regional variability: Manufacturer may declare different content amounts for packaging used in different regions or countries.

4.8.3.2 Minimum postconsumer content guidelines

An optional product criterion

All packaging shall meet or exceed the minimum postconsumer content level for respective packaging in the U.S. EPA Comprehensive Procurement Guidelines.

4.8.4 Take-Back Option

4.8.4.1 Provision of take-back program for packaging

An optional product criterion

The marketing and sale to institutions of all covered products shall include a free service whereby the packaging material can be collected and returned to the manufacturer or to a recycler for reuse or recycling.

Regional variability: This criterion may be declared to differently for different regions or countries.

4.8.5 Reuse Option

4.8.5.1 Documentation of reusable packaging

An optional product criterion

Manufacturer shall provide at a competitive price a reusable packaging process that reuses the packaging for a minimum of five reuses for the same or similar product. Certain packaging components are excepted.

Regional variability: This criterion may be declared to differently for different regions or countries.

Aggregated Power Supply Data

Year	Wattage	Min Power	Max Power	Qty. models surveyed	Transistors, approx	Num of Years
1984	46	18	60	3	2.40E+05	0
1986	60	60	60	3	4.80E+05	2
1987	165	100	230	2	6.79E+05	3
1989	99.6	5	159	5	1.36E+06	5
1990	129	50	230	4	1.92E+06	6
1991	80	17	303	6	2.72E+06	7
1992	93.27273	17	303	11	3.84E+06	8
1993	107.3182	17	303	22	5.43E+06	9
1994	105.4118	17	303	17	7.68E+06	10
1995	96	36	225	16	1.09E+07	11
1996	173.6364	45	325	11	1.54E+07	12
1997	202.0833	45	390	12	2.17E+07	13
1998	142	45	300	5	3.07E+07	14
1999	127.7778	45	200	9	4.34E+07	15
2000	142	45	338	9	6.14E+07	16
2001	146.2222	45	338	9	8.69E+07	17
2002	162.4545	55	400	11	1.23E+08	18
2003	189.4286	47	700	14	1.74E+08	19
2004	259.375	50	700	8	2.46E+08	20
2005	250.5556	50	700	9	3.48E+08	21
2006	137.3077	0	650	13	4.92E+08	22
2007	93.83333	48	200	6	6.95E+08	23
2008	147.7778	0	750	9	9.83E+08	24
2009	223.8125	0	1440	16	1.39E+09	25
					1.97E+09	26