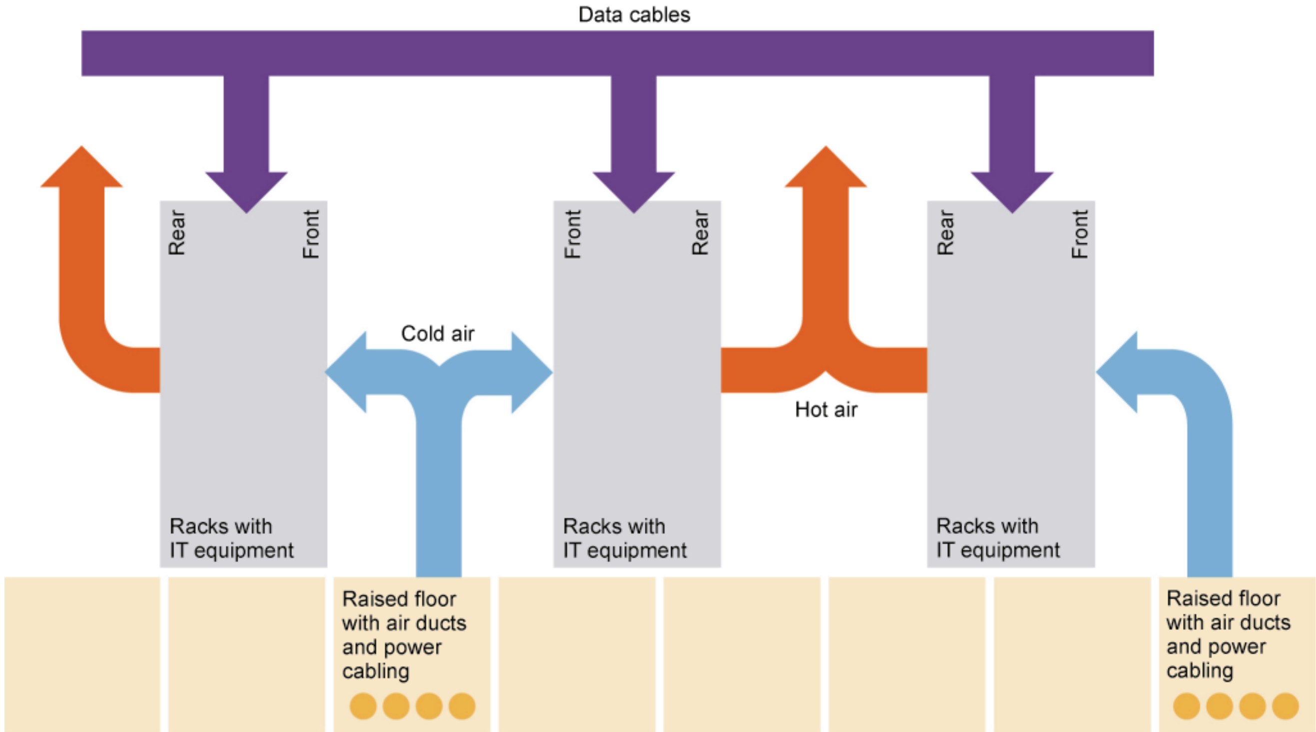
Green Sustainable Data Centres

Introduction to Green IT



This course is produced under the authority of e-Infranet: http://e-infranet.eu/

Course team
prof. dr. Colin Pattinson, Leeds Beckett University (United Kingdom),
course chairman and author of Chapter 1 and 7
prof. dr. Ilmars Slaidins, Riga Technical University (Latvia*),*
assessment material development: Study Guide
dr. Anda Counotte, Open Universiteit (The Netherlands),
distance learning material development, editor- in-chief
dr. Paulo Carreira, IST, Universidade de Lisboa(Portugal),
author of Chapter 8
Damian Dalton, MSc, University College Dublin (Ireland),
author of Chapter 5 and 6
Johan De Gelas, MSc, University College of West Flanders (Belgium),
author of Chapter 3 and 4
dr. César Gómez-Martin, CénitS - Supercomputing Center and
University of Extremadura (Spain),
author of Checklist Data Centre Audit
Joona Tolonen, MSc, Kajaani University of Applied Sciences (Finland),
author of Chapter 2

Program direction
prof. dr. Colin Pattinson, Leeds Beckett University (United Kingdom),
prof. dr. Ilmars Slaidins, Riga Technical University (Latvia)
dr. Anda Counotte, Open Universiteit (The Netherlands)

Hosting and Lay-out
http://portal.ou.nl/web/green-sustainable-
data-centres
Arnold van der Leer, MSc
Maria Wienbröker-Kampermann
Open Universiteit in the Netherlands

First edition 2014

Introduction to Green IT

Chapter 1

Introduction to Green IT

Colin Pattinson and Ah-Lian Kor
Leeds Metropolitan University

INTRODUCTION

Man-made global warming

This chapter *Introduction to Green IT* will focus on the technical issues of Green IT. It aims to identify the contribution of IT to the environmental problems which contribute to *man-made global warming*. In particular, the focus is on data centres, which are a major component of contemporary IT systems, and are responsible for a large share of the IT industry's emissions. The chapter then addresses the potential for changes in the operation of data centres which can result in reduced energy, emissions and operational cost. An introduction to the EU code of conduct on data centres, on which this course is based, introduces the need for measurement and metrics.

This chapter is relevant to those who are currently in a junior management / higher technical role who wish to progress their career by developing the Green IT agenda within an organisation.

LEARNING OBJECTIVES
After you have studied this chapter, you are expected to:
– Know the definitions of key terms relevant to the debate over Green ICT
– Understand the context of ICT and its contribution to energy consumption.
– Understand the opportunity for changes in operation of data centre
– Get awareness on the need for measurement and control in data centre.

Study hints
The purpose of this chapter is to make you aware of the issues in green IT and the possible solutions. We do this by giving you an impression of the material that is available on this subject. It is not the purpose that you reproduce the details. The details that are important for the assessment of a data centre will be given in the next chapters.

Ibid

In this chapter we use the term *ibid*; it is Latin, short for ibidem, meaning 'in the same place' and is the term used to provide an endnote or foot-note citation or reference for a source that was cited in the preceding endnote or footnote.
The workload is 12 hours.

CORE OF STUDY

1 IT and the Environment

1.1 CLIMATE CHANGE

1.1.1 *Greenhouse Effect and Carbon Cycle*

Greenhouse gases (GHG)
Water vapour
Carbon dioxide
Methane
Nitrous oxide
Fluorinated gases

The EPA (United States Environmental Protection Agency) and NASA have given an excellent overview of *greenhouse gases (GHG)*[1,2] which are gases that trap heat in the atmosphere. They are: *water vapour* – due to natural evaporation of water and industrial processes; *carbon dioxide* – produced by burning natural or synthetic organic substances (e.g. fossil fuels, trees, etc.); *methane* – emitted by natural sources such as wetlands, livestock, decay of organic waste, etc.; *nitrous oxide*–direct effect of human activities such as agriculture, fossil fuel combustion, wastewater management, and industrial processes; *fluorinated gases* (also known as ozone depleting substances) -emitted from a variety of industrial processes.

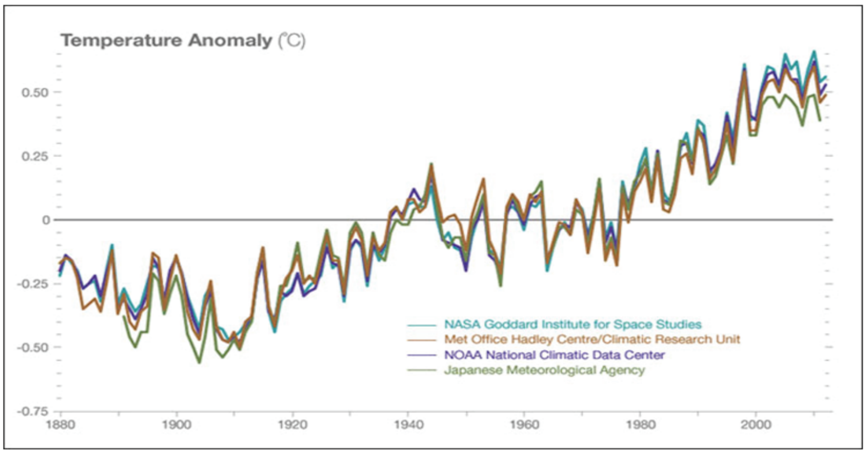
According to IPCC (2007) [3], global greenhouse gas emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (28.7 to 49 Gigatonnes of carbon dioxide equivalents ($GtCO_2$-eq – refer to footnote[4]). The emissions of the various greenhouse gases have increased at different rates, however, CO_2 emissions have grown between 1970 and 2004 by about 80%.

REFLECTION 1
What is the impact of Greenhouse Gases on our environment?

Increased human activities
Greenhouse Effect
Carbon Cycle

According to the International Panel on Climate Change, IPCC (2013)[5] , the globally averaged combined land and ocean surface temperature data show a warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C. Climate scientists agree that the current trend of global warming (as shown in Figure 1) is due to *increased human activities* which have a direct or indirect impact on the *Greenhouse Effect* and *Carbon Cycle*.

[1] http://www.epa.gov/climatechange/ghgemissions/gases.html
[2] http://climate.nasa.gov/causes
[3] http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4_wg3_full_report.pdf
[4] "Gt CO2 eq" stands for the units of total emissions of greenhouse gases and particles in equivalent carbon dioxide units (including the "Kyoto gases": CO2, CH4, N2O, HFCs, PFCs, and SF6).
[5] http://www.climatechange2013.org/images/uploads/WGI_AR5_SPM_brochure.pdf



Temperature data from four international science institutions. All show rapid warming in the past few decades and that the last decade has been the warmest on record.

FIGURE 1 Global Warming Trend [6]

Greenhouse effect is a phenomenon where GH gases in the atmosphere of the earth trap heat from the sun and thus keeping it warm. However, the amount of retained heat depends on the concentration of these gases in the atmosphere. In the past, this created a balanced environment which has allowed life to develop. However, the increased CO_2 and other gases – both natural and man-made – have created a so-called *enhanced green-house effect*, where more heat is trapped[7]. Do Task 1 to help you better understand this phenomenon.

Enhanced greenhouse effect

Task 1
Animation of Greenhouse Effect by the National Geographic
http://environment.nationalgeographic.co.uk/environment/global-warming/gw-overview-interactive/

Watch video on Greenhouse Effect by EPA
http://epa.gov/climatestudents/basics/today/greenhouse-effect.html

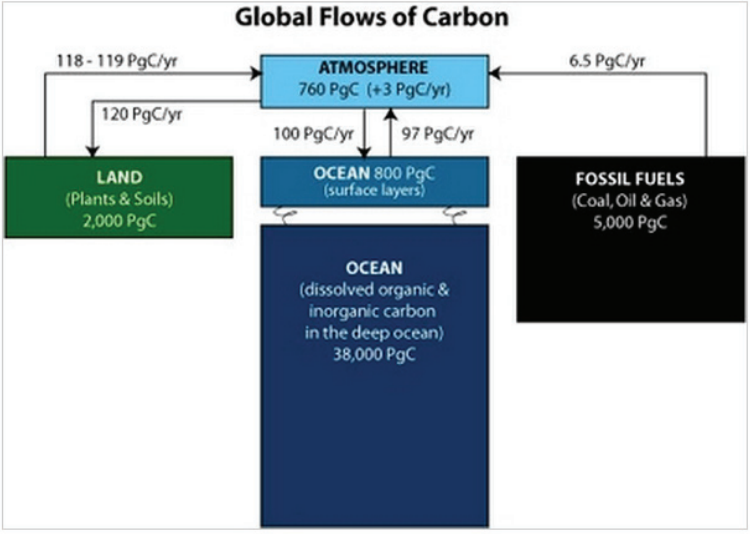
According to the American Heritage Science Dictionary (2005)[8], a carbon cycle is defined in terms of a series of ecosystem processes which involves a continuous exchange of carbon between organisms and the environment. Carbon dioxide is absorbed from the atmosphere by plants and algae and converted to carbohydrates by photosynthesis. Carbon is then passed into the food chain (as organic compounds) and returned to the atmosphere as carbon dioxide, by the respiration and decay of animals, plants, and other organisms. The burning of fossil fuels also releases carbon dioxide into the atmosphere.

[6] http://climate.nasa.gov/scientific-consensus
[7] http://jncc.defra.gov.uk/page-4389
[8] http://www.thefreedictionary.com/carbon+cycle

Task 2
Watch video on Carbon Cycle by EPA
http://epa.gov/climatestudents/basics/today/carbon-dioxide.html

Draw a simple carbon cycle.

REFLECTION 2
What is a global carbon cycle?



Note: PgC/yr is Petagram (or 1 billion metric tonnes) Carbon per year

FIGURE 2 Global Carbon Flux[9]

The global carbon flux given by Nasa (ibid) are as follows (see Figure 2):
– the total amount of carbon in the ocean is approximately 50 times more than that in the atmosphere;
– at least half of the oxygen we breathe comes from the photosynthesis of marine plants;
– 48% of the carbon emitted to the atmosphere by fossil fuel burning currently 'sinks' into the ocean.

Even though the ocean acts as a valuable carbon sink, its future role remains uncertain due to potential climate change impacts that you will see in the next section.

[9]http://science.nasa.gov/earth-science/oceanography/ocean-earth-system/ocean-carbon-cycle/

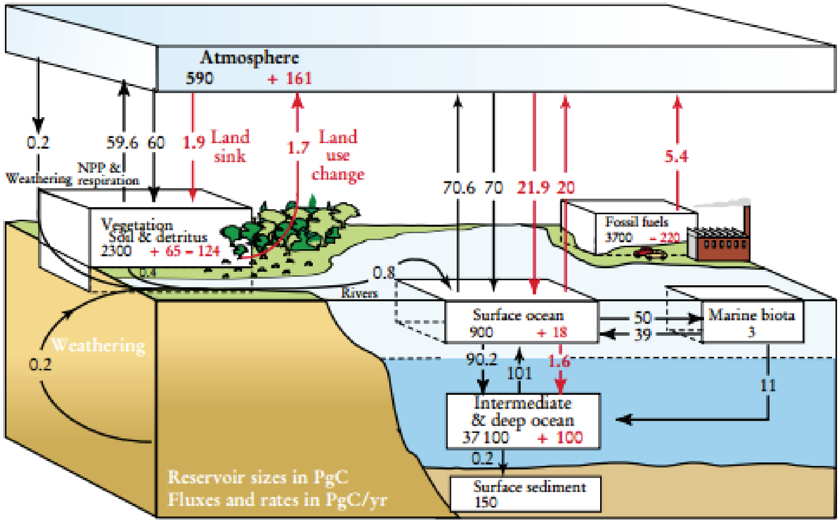


FIGURE 1. GLOBAL CARBON CYCLE. Arrows show the fluxes (in petagrams of carbon per year) between the atmosphere and its two primary sinks, the land and the ocean, averaged over the 1980s. Anthropogenic fluxes are in red; natural fluxes in black. The net flux between reservoirs is balanced for natural processes but not for the anthropogenic fluxes. Within the boxes, black numbers give the preindustrial sizes of the reservoirs and red numbers denote the changes resulting from human activities since preindustrial times. For the land sink, the first red number is an inferred terrestrial land sink whose origin is speculative; the second one is the decrease due to deforestation.[16] Numbers are slight modifications of those published by the Intergovernmental Panel on Climate Change.[3] NPP is net primary production.

FIGURE 3 Global Carbon Cycle (ibid, page 31)

Figure 3 depicts the global carbon sources, sinks and fluxes.

Task 3
Read this article entitled 'Sinks for Anthropogenic Carbon' by Gruber & Sarmiento (2002)[10].

Read this chapter entitled 'The Carbon Cycle and the Climate System' by IPCC (2007)[11].

REFLECTION 3
What are the causes and effects of a climate change?

1.1.2 *Effects of Climate Change*

Disasters

Undeniably, the increasing global temperatures have a detrimental effect on our climate which will inadvertently result in many current and future disasters as shown in Figure 4. The consequences are: floods due to rising sea water level, wildfires and prolonged droughts caused by higher temperatures, increased occurrence, intensity and duration of tropical storms, etc.[12] Try out the simulation in Task 4.

[10] http://www.ocean.washington.edu/courses/oc400/sarmientogruber.pdf
[11] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7-3.html
[12] http://climate.nasa.gov/effects, http://news.bbc.co.uk/1/hi/6528979.stm, http://www.epa.gov/climatestudents/impacts/signs/temperature.html

The quiz in Task 5 will help assess your knowledge on global warming.

FIGURE 4 Effect of a Climate Change[13]

Task 4
The Coming Flood: Explore the future's rising sea
http://sealevel.newscientistapps.com/
This simulation (developed by the journal New Scientist) shows how the sea level will rise as the world warms over the coming decades.

Task 5
Take a quiz on global warming by the National Geographic
http://environment.nationalgeographic.co.uk/environment/global-warming/quiz-global-warming

REFLECTION 4
What has the world collectively done to mitigate the effects of climate change?

1.1.3 *Kyoto Protocol*

Agreement

Emission reduction targets

The Kyoto Protocol[14,15]is an international *agreement* linked to the United Nations Framework Convention on Climate Change. It was adopted in Kyoto, Japan, on 11 December 1997 and to date, parties that have adopted the protocol are found here[16]- the European Union declaration is in this website[17]. Parties involved are committed to set internationally binding *emission reduction targets* for main greenhouse gases (e.g. carbon dioxide, methane, nitrous oxide, and fluorinated gases). The enforcement of the Kyoto Protocol is partitioned to several phases. In the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. The second phase of the Kyoto Protocol is the second commitment period where parties involved (note: the composition of this group is different from the first) committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020. This second commitment is the result of an amendment to the Kyoto Protocol, the Doha Amendment[18], which was adopted in

[13]http://www.epa.gov/climatestudents/impacts/signs/index.html
[14]http://unfccc.int/kyoto_protocol/items/2830.php
[15]http://unfccc.int/resource/docs/convkp/kpeng.pdf
[16]http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php
[17]http://unfccc.int/kyoto_protocol/status_of_ratification/items/5424.php
[18]https://unfccc.int/kyoto_protocol/doha_amendment/items/7362.php

December, 2007. For 2020, the EU has committed to reducing its emissions to 20% below 1990 levels as outlined in the Europe 2020 growth strategy[19] while EU's GHG emissions reduction target for 2050 will be80-95% compared to 1990 levels.

1.2 ENVIRONMENTAL IMPACT OF ICT

1.2.1 *Introduction*

Mobile revolution

The International Telecommunications Union, ITU (2013)[20] has provided vital statistics on ICT use which evidently shows an increasing trend of universal growth in ICT uptake. This is attributed to the *mobile revolution* which delivers ICT applications in education, business, government, banking, health, etc. (ibid). According to ITU, in 2013, there are almost as many mobile-cellular subscriptions as people in the world.

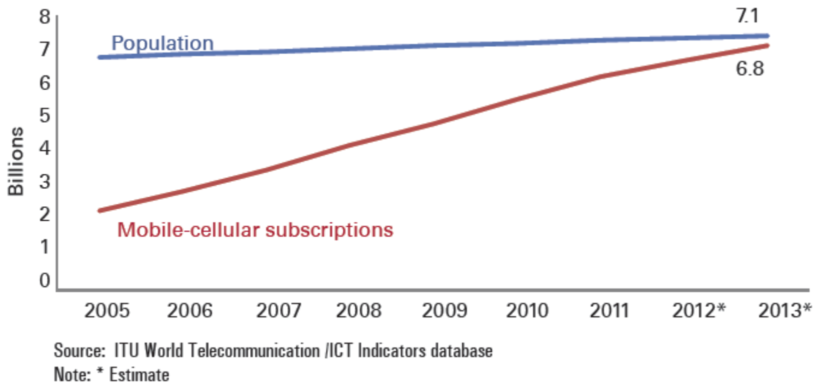


FIGURE 5 Global Population versus Mobile-Cellular Growth (ibid, p. 1)

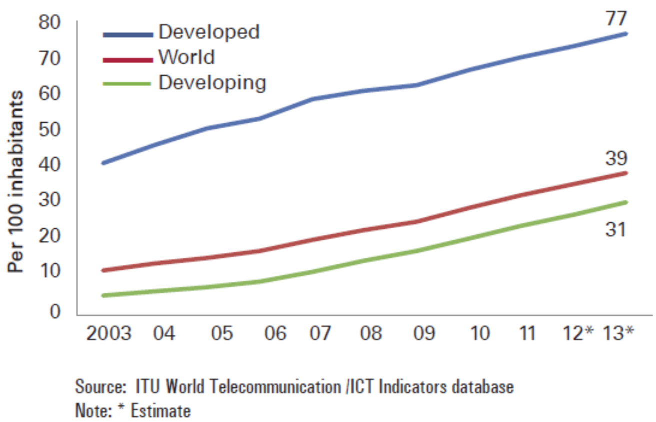


FIGURE 6 Internet Users by Country Development Level (ibid, p. 2)

[19]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF
[20]http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf

Internet

Based on ITU's statistics (Figure 6), in 2013, more than 2.7 billion people are using the *Internet*, which is 39% of the world's population. As for the developing world, 31% of its population has online experience while it is 77% for the developed world.

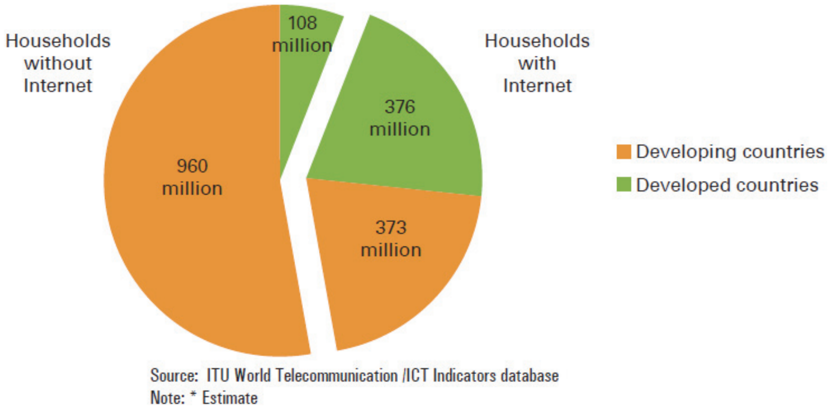
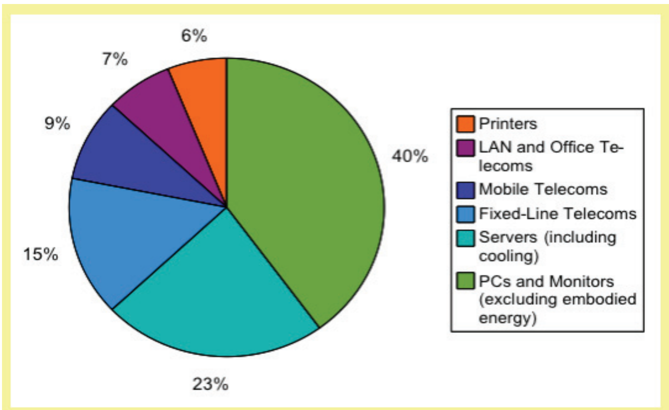


FIGURE 7 Households with Internet Access 2013 (ibid, p. 3)

The facts and figures provided by ITU in Figure 7 shows that in 2013, 41% (equivalent to 749 million) of the world's households are connected to the Internet. Half of them are in the developing world with household Internet penetration of approximately 28% while it is 78% for the developed world. However, 1.1 billion households are not connected to the Internet, and a proportion of 90% is from the developing world.

REFLECTION 5
What is the impact of increased ICT uptake on the environment?



Note: This analysis does not include radio-broadcasting equipment or TV sets. It is based on a global estimate of 0.9 Gt CO_2eq.

Source: R. Kumar and L. Mieritz, "Conceptualizing 'Green IT' and data centre power and cooling issues," Gartner Research Paper No. G00150322, Sep. 2007.

FIGURE 8 Estimated Distribution of GlobalCO_2 emission for ICT's (extracted from ITU,2009, p.4)[21]

[21]http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00600C0004PDFE.pdf,

Aviation industry

Statistics in the preceding section have shown an increasing trend of ICT use and its growth rate could surpass that of the *aviation industry*. Consequently, the ICT-related energy use is comparable to that of the aviation industry (UK Parliamentary Office of Science and Technology (2008)[22]. ICT's substantial energy consumption has a significant impact on GHG emissions and climate change where 2% of global carbon emissions come from manufacturing and using of Information and Communication Technology (ICT)[23]. In Europe, ICT equipment and services account for 2.5%-4% for EU's carbon emissions[24]. According to the Smart2020[25] report by the Global e-Sustainability Initiative, GeSI (2008), the ICT sector's emissions are expected to increase, from 0.53 billion tonnes (Gt) carbon dioxide equivalent (CO_2e) in 2002 to 1.43 $GtCO_2e$ in 2020 (in Business As Usual, BAU, scenario). Figure 8 shows the estimated distribution of global CO_2 emission for ICT during its *use phase*. The main contributors are PC's and monitors (40%), telecommunications (31%), followed by data centres (23%).

Use phase

REFLECTION 6
The Smarter2020[26]predicts a decreasing growth rate of CO2 emissions for the ICT industry? Why?

Task 6
Read the ICT industry GHG emissions in Smarter2020[27] report (pages 21-26). List the factors which drive the decrease in the ICT emissions growth rate (shown in Figure 9).

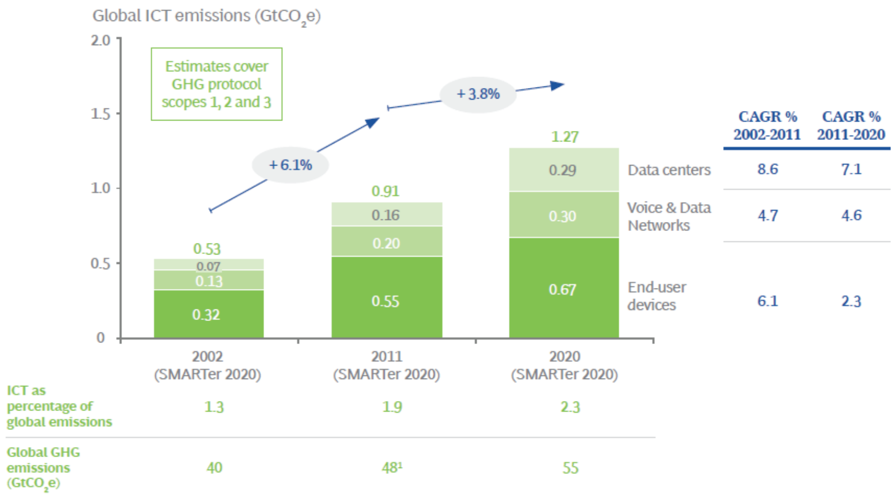


FIGURE 9 ICT emissions growth rate (ibid, p.21)

[22]http://www.parliament.uk/documents/post/postpn319.pdf
[23]http://globalactionplan.org.uk/sites/gap/files/Green%20ICT%20Handbook.pdf, http://www.gartner.com/newsroom/id/503867
[24]http://ec.europa.eu/digital-agenda/en/pillar-vii-ict-enabled-benefits-eu-society/action-69-assess-whether-ict-sector-has-complied-common
[25]http://gesi.org/files/Reports/Smart%202020%20report%20in%20English.pdf
[26]http://gesi.org/SMARTer2020
[27]http://gesi.org/assets/js/lib/tinymce/jscripts/tiny_mce/plugins/ajaxfilemanager/uploaded/SMARTer%202020%20-%20The%20Role%20of%20ICT%20in%20Driving%20a%20Sustainable%20Future%20-%20December%202012.pdf

In Figure 9, the emissions growth rate for three ICT categories (end-user devices, telecommunication and networks, and data centres) is expected to decrease from 6.1% to 3.8% (ibid, p. 21). By 2020, the ICT industry's footprint is expected to rise to 1.3 GtCO2e (equivalent to 2.3% of global emissions by 2020). The estimated data centre footprint growth rate is the highest (7.1% annually), followed by networks (4.6%) and end-user devices (2.3%, and note that this footprint is the largest in 2011, ibid).

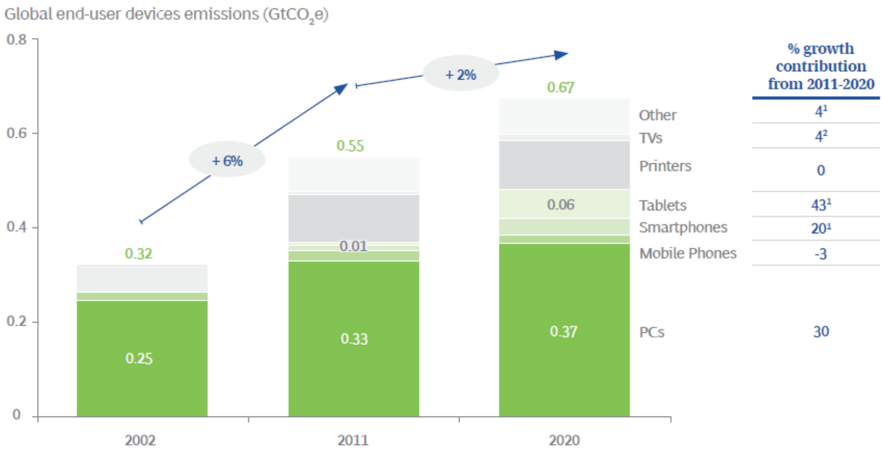


FIGURE 10 End-user Devices emissions growth rate (ibid, p. 22)

All the facts and figures in this section have been extracted from the Smarter2020 report. In Figure 10, PC footprint (due to its embodied and usage emissions) is the highest (60%) followed by printers (18%), peripherals (13%), smartphones (10%), and tablets (1%). It is estimated that the footprint of end-user devices will grow at 2.3 percent per year to reach 0.67 GtCO2e in 2020 and thus, energy efficiency improvements (further discussed in the Green IT Section) in these devices are essential for reducing their overall footprint.

REFLECTION 7

Why is the wireless networks emission growth rate expected to surpass that of the wired networks by 2020?

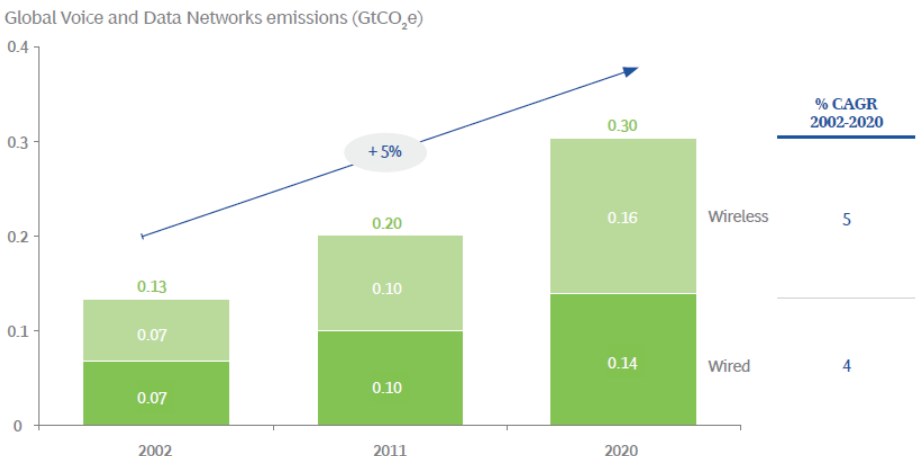


FIGURE 11 Networks emissions growth rate (ibid, p. 23)

According to Smarter2020 report, the total mobile data and voice traffic is expected to increase by 33-70 times. Some of the contributing factors to this rapid growth are: increase in mobile subscriptions (6 billion in 2011) and increased data usage per user (due to data-intensive services and applications). Wireless network emissions are modelled as a function of traffic growth and the estimated wireless network emissions is 162 $MtCO_2e$ in 2011 (assumption: data growth is 50 times). On the other hand, wireline emissions are estimated to have a CAGR (Compound Annual Growth Rate) of 4% from 2011 to 2020. The estimated amount of emissions by 2020 will be 0.14 $GtCO_2e$ (see Figure 11).

REFLECTION 8
Why will the data centre emissions growth rate be the highest compared to the other two ICT categories (end-user devices and networks)?

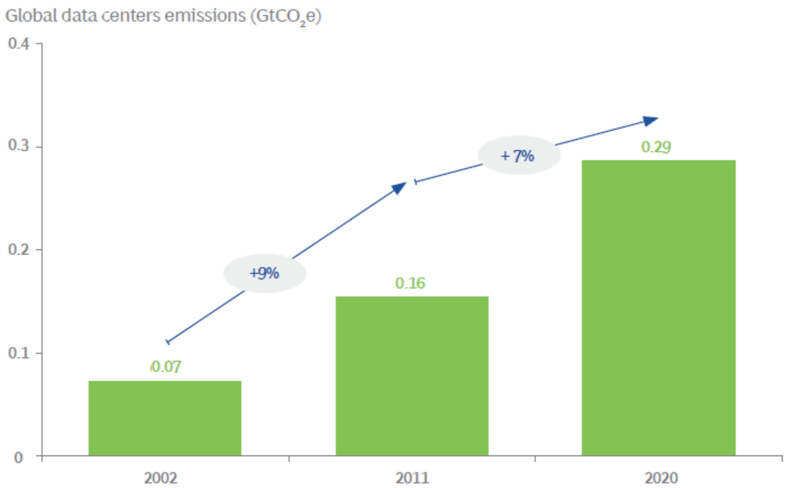


FIGURE 12 Data Centre emissions growth rate (ibid, p. 25)

In 2011, the data centre footprint is the smallest compared to other ICT categories and its emissions are only 0.16 $GtCO_2e$ (i.e. 17% of the total ICT emissions). However, by 2020, the emissions are expected to grow by 7% resulting in a footprint of 0.29 $GtCO_2e$. The main reason for this rapid growth is an increased demand for data storage due to increased cloud uptake. However, energy efficiency improvement techniques will reduce the emissions growth rate.

REFLECTION 9
What is the relationship between energy use and GHG emissions?

The environmental impacts of ICT are not merely confined to energy use and greenhouse gases but also e-waste, hazardous waste, and water usage[28] and the depletion of scarce materials.

[28]http://www.sustainability-perspectives.com/perspective/four-key-factors

1.2.2 *Energy Use and GHG emissions*

ICT is a large consumer of energy. According to the World Summit for an Information Society, electricity demand by the ICT sector for industrialised countries is between 5% and 10% of total electricity demand[29]. ICT equipment and services comprises approximately 8% of Europe's energy use[30]. You should consider whether the proportion in your own country is higher or lower than this average value.

REFLECTION 10
What is e-waste and what are the measures that could be taken to reduce e-waste?

1.2.3 *E-Waste*

The European has drawn a list of different categories of electrical and electronic equipment (EEE) which includes IT and telecommunications equipment[31]. According to the UK Environmental Agency (EA), "if an item of EEE has been discarded by the holder into any waste collection system it will become WEEE"[32]. However, WEEE Directive 2003[33] provides a more technical definition for e-waste.

Task 7
Compare the definitions of e-waste provided by the UK Environmental Agency and WEEE Directive 2003.

Based on the WEEE Recast Directive (2012)[34], new rules will be introduced to manage (i.e. collect and treat) e-waste for resource efficiency. Some of the new laws are: from 2016 EU member states will have to collect 45 tonnes of e-waste for every 100 tonnes of electronic goods put on sale during the previous three years; by 2019 the target must rise to 65 tonnes, or member states can opt to collect 85% of total e-waste generated[35].

1.2.4 *Hazardous Waste*

Lithium rechargeable batteries[36] have been used for laptops, PDAs, tablets, and mobile devices. The two different types of Lithium batteries are: Lithium ion (Li-ion or LIB) and Lithium ion polymer (Li-poly, Li-Pol, LiPo, LIP, PLI, etc.)[37] batteries. According to Apple Inc, the latter is more preferable because they have a high power density that results in a longer battery life within a light package and also a faster charge rate[38].

---

[29] http://www.unep.org/resourceefficiency/Home/Business/SectoralActivities/ICT/ICTClimateChange/tabid/78948/Default.aspx
[30] https://ec.europa.eu/digital-agenda/en/news/recommendation-mobilising-ict-facilitate-transition-energy-efficient-low-carbon-economy
[31] http://europa.eu/legislation_summaries/environment/waste_management/l21210_en.htm
[32] http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT_7606_d08a89.pdf
[33] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0024:0038:EN:PDF
[34] http://europa.eu/rapid/press-release_IP-12-898_en.htm
[35] http://www.bbc.co.uk/news/world-europe-16633940
[36] http://ec.europa.eu/environment/waste/batteries/pdf/battery_report.pdf (pages 35-36)
[37] http://www.wordreference.com/es/translation.asp?tranword=lithium%20lithium%20ion%20polymer%20battery%20Li%20poly%20Li%20Pol%20LiPo%20LIP%20PLI%20LiP%20battery
[38] http://www.apple.com/uk/batteries/

In the EU, all batteries are subjected to the Battery Directive (2006/66/EC)[39] because all batteries contain hazardous compounds that are harmful to the environment. According to the EC (ibid), when batteries are incinerated, the metals they contain pollute the atmosphere and the incineration residues pollute the soil. However, when batteries end up in landfills, the metals can leach into the soil and water. Thus, the chemical substances in batteries can cause atmospheric, soil, and water pollution.

The International Air Transport Association, IATA, has drawn up a set of guidelines for the transportation, and handling of lithium batteries[40] while2006 European Union (EU) Directive[41] on Batteries and Accumulators has established rules for the collection, recycling, treatment, and disposal of batteries (including Lithium batteries).

1.2.5 *Water*

REFLECTION 11
What is water footprinting of ICT?

Fresh water
Lifecycle
Cool

According to Hoekstra, et. al (2011)[42], the water footprint of a product is defined as the total volume of *fresh water* used directly or indirectly to produce the product and it is estimated by taking into consideration, the water consumption and pollution in its lifecycle. This means that a water footprint for ICT is the total volume of freshwater used directly or indirectly to: (i) produce an ICT product measured over its *lifecycle* (e.g. cradle to grave); (ii) to *cool* a data centre.

REFLECTION 12
Why is ICT water footprinting important?

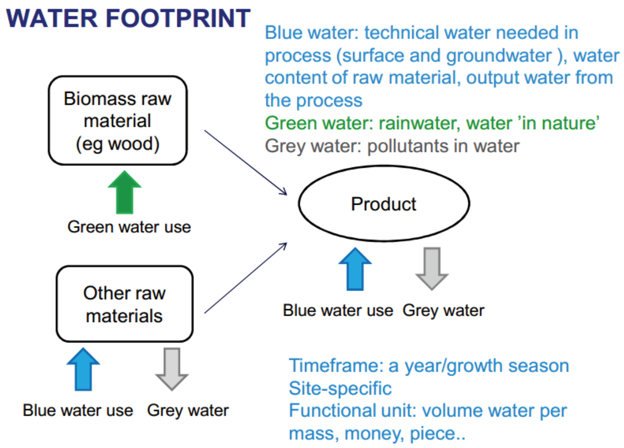


FIGURE 13 Water Footprint for a Product[43]

[39]http://ec.europa.eu/environment/waste/batteries/pdf/qa.pdf
[40]http://www.iata.org/whatwedo/cargo/dgr/Documents/Lithium-Battery-Guidance-2013-V1.1.pdf
[41]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:266:0001:0014:EN:PDF
[42]http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf
[43]http://www.vtt.fi/files/events/Green_VTT_esitykset_071010/7_Wessman_Water_footprint.pdf

According to VTT (2012)[44], the water footprint provides a better understanding and guide for the development of water-saving products, processes, and services. Water footprinting is a tool for understanding and guiding the development of 'water-saving' products, processes, and services. As shown in Figure 13, water footprinting involves accounting throughout the entire product lifecycle. Relevant inventory includes water input and output data for volume, source, and water quality while the impact of water use is assessed in terms of water scarcity indices or level of pollutants (see Figure 14).

In this workbook, we have not discussed all the environmental impacts of ICT. ITU[45] (2011) has categorised the environmental impacts into negative and positive impacts where the former consists of 11 categories.

Task 8
List ITU recommended negative and positive environmental impacts of ICT.

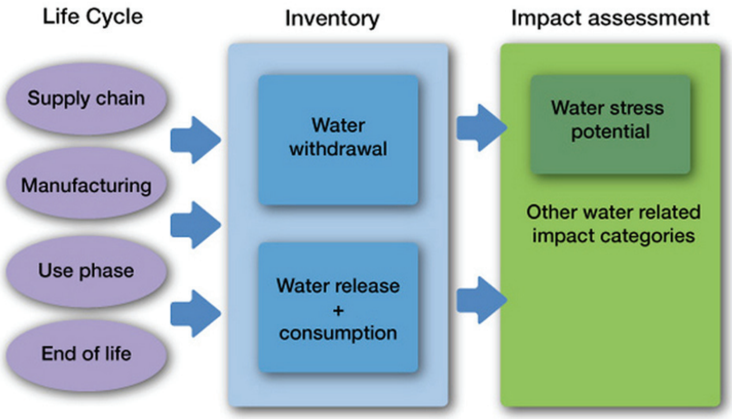


FIGURE 14 Water and Lifecycle Impact assessment (LCIA) of a Product[46]

1.3 ICT AND CLIMATE CHANGE

The Europe2020strategy[47] prioritizes smart, sustainable and inclusive growth. The 20-20-20 targets which are the headline targets of the Europe 2020 strategy, aim to tackle the challenge of climate change while stimulating green growth.

Task 9
Watch this video[48] which captures the Europe 2020 strategy in a nutshell. Reflect on how you could play a part to realise this strategy.

REFLECTION 13
How could ICT impact on the climate change be mitigated?

[44]http://www.vtt.fi/research/technology/water_footprint.jsp?lang=en
[45]http://www.itu.int/rec/T-REC-L.1400-201102-I
[46]http://www.vtt.fi/research/technology/water_footprint.jsp?lang=en
[47]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF
[48]http://ec.europa.eu/commission_2010-2014/hahn/about/vision/index_en.cfm

ICTs play a significant role to limit and reduce GHG emissions. According to the SMART2020 Report[49] there is scope for reducing the carbon footprint of the ICT sector by approximately 36% by 2020 (equivalent 770 Mt CO_2eq) using existing technologies. There are two ways to mitigate ICT impact on climate change[50]. The first is a direct mitigation which reduces the ICT sector's own carbon emissions and energy requirements while the second concerns the exploitation of ICT for offering solutions to reduce the carbon footprint of other sectors and to facilitate efficient and low carbon development. We have used the terms 'Greening of IT' and 'Greening By IT'[51] to encapsulate these two ICT mitigating roles. 'Greening of IT' will be discussed in the next section of this chapter while 'Greening by IT' will be further addressed in Chapter 8. Based on the SMART2020 and SMARTer2020[52] Reports, employing ICT-driven efficiency across the economy will deliver emission savings. The latter demonstrates how the increased use of ICT could reduce the projected 2020 global greenhouse gas (GHG) emissions by 16.5% (equivalent to 9.1 $GtCO_2e$) and this is more than seven times the ICT sector's emissions in the same period.

Literature

GeSI. (2008). Smarter2020, The Role of ICT in Driving a Sustainable Future, http://gesi.org/SMARTer2020 , accessed date: 6th December, 2013.

Global Action Plan. (2007). The Inefficienct Truth, http://www.it-energy.co.uk/pdf/GAP%20An%20Inefficient%20Truth%20Dec%202007.pdf, accessed date: 6th December, 2013.

Global Action Plan. (2009). Green ICT Handbook: A Guide to Green ICT, http://globalactionplan.org.uk/sites/gap/files/Green%20ICT%20Handbook.pdf, accessed date: 6th December, 2013.

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, in press. http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_All.pdf, accessed date: 6th December, 2013.

ITU. (2013). The World 2013: ICT Facts and Figures, http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf, accessed date: 6th December, 2013.

World Bank (2010). World Development Report 2010, http://web.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/0,contentMDK:23079906~pagePK:478093~piPK:477627~theSitePK:477624,00.html, accessed date: 11th December, 2013.

[49] http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf
[50] http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00600C0004PDFE.pdf
[51] http://www.bcs.org/content/conWebDoc/41890
[52] http://gesi.org/SMARTer2020

2 Green IT

2.1 DEFINITION OF GREEN IT

Many terms have been used synonymously with 'Green IT'. They are 'Green Computing', 'Green ICT', 'Sustainable Computing', 'Sustainable IT', 'Environmental Sustainable IT', 'Environmental-friendly IT or Computing', etc. The definition of Green IT given by the IEEE Computer Society[53] is strategy-focused. A narrow definition of Green IT refers to strategies for reducing energy consumption and the environmental impact of products, equipment, services and systems. On the other hand, a broader definition of Green IT encompasses strategies which address environmental and social issues, government policies, and also considering innovative as well as ecologically responsible ways for the exploitation of computing resources. Murugesan's[54](2013) definition of Green IT is environment sustainability-focused. It refers to environmentally friendly computer, information systems, applications, and practices which aim to improve energy efficiency, lower GHG emissions, use of less toxic materials, encouraging reuse and recycling.

Task 10
List approaches for improving the sustainability of our environment using ICT.

The approaches that you have listed in Task 10 could be grouped into two categories:

Greening of IT

– *Greening of IT*– aims to mitigate the environmental impact of ICT itself. This encompasses energy efficient and environmental sustainable designs, operations, use and disposal of ICT equipment, infrastructure and systems;

Greening by IT

– *Greening by IT*–aims to harness IT (via ICT-enabled solutions) to mitigate the environmental impact of other sectors. In SMARTer2020[55], the named sectors are: power, transportation, manufacturing, agricultural, building, service and consumer. This addresses applying ICT to create energy-efficient and environmental sustainable operations, processes, practices, etc. (Note: this will be further discussed in Chapter 8).

In this course we use 'Green' to describe those situations when only the impact on the environment is considered. We use 'Sustainable' for situations which affect the 'triple P' People, Planet, Profit, derived from the Brundtland definition and relating to Corporate Social Responsibility.

Sustainability is the act of striving for equilibrium in the triangle People, Planet, Profit with the target of less 'wastage'. Balance with respect to Profit and People means no waste of money or working hours by failure of IT-projects; promotion of code reuse and code without failures.

[53] http://www.computer.org/portal/web/buildyourcareer/JT28
[54] http://www.computer.org/portal/web/computingnow/archive/april2013
[55] http://gesi.org/SMARTer2020

Balance between Profit and Planet means among other things energy efficiency of hardware and software and careful e-waste. Balance between People and Planet means an attitude of respect for the planet and knowledge of Sustainability of and by IT. According to Murugesan this can be achieved by an holistic approach[56].

REFLECTION 14
What do you understand by ICT infrastructure?

2.2 OVERVIEW OF GREENING OF IT

ITU[57] (2011) has provided the definitions for the following: ICT goods, ICT networks, and ICT services.

According to Laudon and Laudon (2010)[58], IT infrastructure consists of a set of physical devices, software applications and IT related services. Five major IT infrastructure components are: hardware, software, data management, networking, and services (see Figure 15). This chapter will only focus on green hardware and networks.

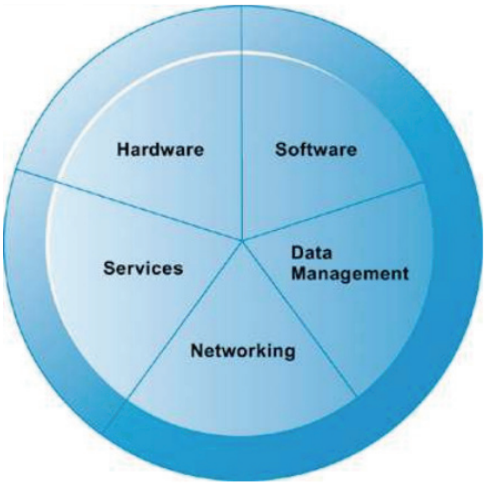


FIGURE 15 IT Infrastructure Major Components (Laudon and Laudon, 2011)[59]

REFLECTION 15
What is ENERGY STAR?

[56] Murugesan, S. (2012). Harnessing Green IT: Principles and Practices, John Wiley International and IEEE Computer Society (pages 6-8)
[57]http://www.itu.int/rec/T-REC-L.1400-201102-I
[58] Laudon and Laudon (2010).Management Information Systems: Managing the Digital Firm, (11th edition),Pearson/PrenticeHall http://www.pearsoned.ca/highered/showcase/laudon/pdf/9780135078853_ch05.pdf
[59]Laudon and Laudon (2011). Essentials of MIS, Chapter 4: IT Infrastructure: Hardware and Software, 9th Edition, ISBN: ISBN13: 9780273765462, url: http://ramayah.com/wp-content/uploads/2011/12/CH4.pdf

2.3 ENERGY EFFICIENCY AND ENERGY STAR

Originally, the ENERGY STAR[60] is a U.S. Environmental Protection Agency (EPA) voluntary program that promotes energy savings and efficiency in ICT products. It has boosted the adoption of energy efficient products, practices, and services. As a result of this, it has been instrumental in reducing greenhouse gases emissions.

However, the European Union Community Energy Star Board (ECESB) and the US EPA signed a new Energy Star * agreement[61] on 28 December 2006. They regularly adapt and re-assess technical specifications applied to ICT equipment (e.g. computers, computer displays, and imaging equipment). A list of certified ICT products is in the Energy Star official website[62]. The ENERGY STAR certification will be extended to data centres[63].

The benefits of ENERGY STAR certification are as follows[64,65]:
– if every home office product purchased in the United States is ENERGY STAR certified, the estimated annual savings is 1.5 billion pounds of greenhouse gas emissions (equal to emissions from 158,000 cars), energy savings of more than $117 million;
– A certified computer will use 30 to 65 percent less energy, depending on how it is used;
– Averagely, certified monitors are 20 percent more efficient than standard options;
– Certified imaging equipment is averagely 40 percent more efficient than standard models.

Task 11
Both Carbon Trust and EPA have given practical energy savings tips for ICT equipment. Read the following articles[66,67] and summarise energy savings opportunities for businesses.

Task 12
Use the online ENERGY STAR Office Equipment Savings Calculator to estimate the savings potential for your chosen organisation. Just click on ENERGY STAR Office Equipment Savings Calculator or use the uploaded excel spreadsheet.

REFLECTION 16
What are the differences between EPEAT and ENERGY STAR?

---

[60] http://www.energystar.gov/index.cfm?c=about.ab_index
[61] http://europa.eu/legislation_summaries/consumers/product_labelling_and_packaging/l32053_en.htm
[62] http://www.energystar.gov/certified-products/certified-products
[63] http://www.datacenterknowledge.com/archives/2009/04/22/epa-to-use-pue-in-data-center-energy-star/
[64] http://www.energystar.gov/ia/partners/publications/pubdocs/ENERGY%20STAR%20Office%20Equipment%20Brochure_508.pdf
[65] http://www.dell.com/downloads/global/products/optix/EnergStar5.0_SpecSheet.pdf
[66] http://www.carbontrust.com/media/13113/ctv005_office_equipment.pdf
[67] http://www.energystar.gov/ia/partners/publications/pubdocs/ENERGY%20STAR%20Office%20Equipment%20Brochure_508.pdf

2.4 ELECTRONIC PRODUCT ENVIRONMENTAL ASSESSMENT TOOL (EPEAT)

EPEAT® is the definitive global rating system for greener electronics (ibid) to help purchasers evaluate, compare, and select electronic products based on their environmental attributes[68]. Currently, the EPEAT registry contains more than 3000 products from more than 40 manufacturers from 42 countries[69].

Entire product lifecycle

EPEAT's environmental criteria (shown in Figure 16) encompass the *entire product lifecycle* from design to recycling. Technical details and specifications for each criterion are provided so as to ensure manufacturers' compliances to them.

FIGURE 16 EPEAT's Environmental Criteria (ibid)

EPEAT's categories of products (PCs and PC displays – 1680.1, imaging equipment – 1680.2, and televisions – 1680.3) are based on the IEEE 1680 family of Environmental Assessment Standards[70].

Task 13

Look at the list of optional and required criteria for:

– PC's and PC displays[71]

– Imaging Equipment[72].

[68]http://www2.epa.gov/sites/production/files/documents/epeat_gp_rev.pdf

[69]http://www.epeat.net/documents/purchaser-resources/EPEAT_Basics_Preso_12%200710.pdf

[70]http://www.techstreet.com/ieee

[71]http://www.epeat.net/resources/criteria/#pcanddisplays

[72]http://www.epeat.net/resources/criteria/#imagingequipment

Note that each list in Task 13 consists of 23 required and 28 optional criteria for each category of product. If a product meets all the 23 required criteria then it qualifies for EPEAT. However, each product is rated Bronze, Silver or Gold based on how many of the 28 optional criteria have been met (below 50%, at least 50%, at least 75% respectively)[73].

FIGURE 17 EPEAT Rating Tiers (ibid)

Task 14
Draw a table to compare and contrast EPEAT and ENERGY STAR based on these online resources[74,75].

2.5 80 PLUS CERTIFICATION

Power supplies are the devices that provide power to computers and servers. They convert AC power from electric utilities into DC power used in most electronics. ENERGY STAR has included 80 PLUS requirements in their specifications for computers, and data centres[76]. The 80 Plus program[77], is initiated by the company EPRI Solutions which reveals devices that offer an energy efficiency of at least 80 percent at 20, 50 and 100 percent workload. The 80 PLUS® performance specification[78] requires power supplies in computers and servers to be 80% or greater energy efficient at 10, 20, 50 and 100% of rated load with a true power factor of 0.9 or greater.

Optional Task A
Visit this website[79] if you wish to understand true power factor).

In other words, the 80 PLUS program evaluates computer power supplies for efficiency at 20%, 50% and 100% loads. In order to earn a certification, power supplies only needed to be 80% efficient. However, in order to increase efficiency of power supplies, new standards such as Bronze, Silver, Gold, Platinum, and Titanium were created. Figure 18 shows the different 80 PLUS levels and the corresponding efficiency requirements for each level:

---

[73] http://www.epeat.net/wp-content/uploads/2012/11/Report2012_R6_Full.pdf
[74] http://www2.epa.gov/sites/production/files/documents/epeat_gp_rev.pdf
[75] http://www.epeat.net/documents/purchaser-resources/EPEAT_Basics_Preso_12%200710.pdf
[76] http://www.plugloadsolutions.com/About.aspx
[77] http://www.pcgameshardware.com/aid,692532/80-Plus-What-the-PSU-certification-stands-for/News/
[78] http://www.plugloadsolutions.com/80pluspowersupplies.aspx#
[79] http://www.allaboutcircuits.com/vol_2/chpt_11/2.html

What is 80 PLUS certified? x

80 PLUS Certification	115V Internal Non-Redundant				230V Internal Redundant			
% of Rated Load	10%	20%	50%	100%	10%	20%	50%	100%
80 PLUS	---	80%	80%	80% / PFC .90	---			
80 PLUS Bronze	---	82%	85% / PFC .90	82%	---	81%	85% / PFC .90	81%
80 PLUS Silver	---	85%	88% / PFC .90	85%	---	85%	89% / PFC .90	85%
80 PLUS Gold	---	87%	90% / PFC .90	87%	---	88%	92% / PFC .90	88%
80 PLUS Platinum	---	90%	92% / PFC .95	89%	---	90%	94% / PFC .95	91%
80 PLUS Titanium	---	---	---	---	90%	94% / PFC .95	96%	91%

FIGURE 18 80 PLUS certified standards[80]

Task 15
Go through tutorials 1 to 3 in this website[81] so as to help you understand what 80 PLUS certification is.

REFLECTION 17
Can you name other ecolabels for energy? Try this website82.

3 Overview of a Data Centre

3.1 ENERGY CONSUMPTION AND EFFICIENCY OPPORTUNITIES IN A DATA CENTRE

A data centre is a physical facility which houses an enterprise's networked IT systems, and servers used for data processing, data storage, and communications networking. The following facts on the energy consumption of data centres have been provided by the US Department of Energy (2009)[83]:
– Server racks are now designed for more than 25+ kW
– Typical facility ~ 1MW, can be > 20 MW
– Cost of electricity approaching capital cost of IT equipment
– 1.5% of all electricity in the U.S. in 2006 ($4.5 Billion)
– Growing at 12% per year (will double in 5 years)
– Power and cooling constraints in existing facilities
– Utility distribution constraints

[80] http://www.plugloadsolutions.com/80pluspowersupplies.aspx#
[81] http://www.hardwaresecrets.com/article/742
[82] http://www.ecolabelindex.com/ecolabels/?st=category,energy
[83] http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/doe_data_centres_presentation.pdf

Figure 25 provides an overview of energy efficiency opportunities for a green data centre and a detailed discussion is found in Chapter 2-5 of this workbook.

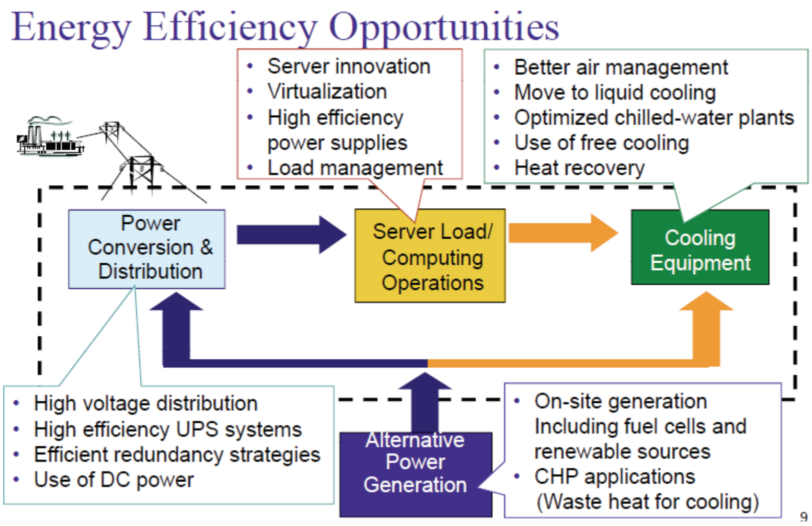


FIGURE 25 Energy Efficiency Opportunities for a green data centre (ibid)

3.2 METRICS IN A DATA CENTRE

Table 1 shows the metrics used to measure the efficiency of a data centre.

TABLE 1 Green Data Centre Metrics (adapted from Murugesan et. al, 2012)

Metric Acronym	Metric Name	Formula or detail	Unit	Reference
PUE	Power Usage Effectiveness	Total data centre energy / Total IT equipment energy	No unit	Green Grid[84] BCS[85]
DCiE	Data Centre infrastructure Efficiency	1 / PUE Total IT equipment energy x 100% / Total data centre energy	No unit	BCS (ibid)
CUE	Carbon Usage Effectiveness	Total CO_2 emissions by the Total data centre energy / Total IT equipment energy CEF x PUE	$kgCO_2eq/kWh$	Green Grid[86]
WUE	Water Usage Effectiveness (site)	Annual Site Water Usage / Total IT equipment energy	L/kWh	Green Grid[87]
WUE_{source}	Water Usage Effectiveness (site + source)	Annual Source Energy Water Usage Annual Site Water Usage / Total IT equipment energy	L/kWh	Green Grid (ibid)

Note: CEF – Carbon Emission Factor

[84] http://www.thegreengrid.org/~/media/WhitePapers/DCcE_White_Paper_Final.pdf?lang=en
[85] http://www.bcs.org/upload/pdf/data-centre-energy.pdf
[86] http://www.thegreengrid.org/~/media/WhitePapers/Carbon%20Usage%20Effectiveness%20White%20Paper_v3.pdf?lang=en
[87] http://www.thegreengrid.org/~/media/WhitePapers/WUE

Definitions of green data centre metrics by Green Grid and BCS Data Centre Working Group are as follows:

PUE: the fraction of the total data centre energy divided by the IT equipment energy. Ideal value is 1.0.

DCiE: the fraction of the IT equipment energy divided by the total data centre energy.

CUE: to address carbon emissions associated with data centres. The numerator is the total carbon emissions caused by the use of the energy in the PUE metric. Ideal value is 0.0.

WUE: a site-based metric that is an assessment of the water used on-site for operation of the data centre. This includes water used for humidification and water evaporated on-site for energy production or cooling of the data centre and its support systems

WUE_{source}: a source-based metric that includes water used on-site and water used off-site in the production of the energy used on-site. Typically this adds the water used at the power-generation source to the water used on-site.

In Chapter 2 we will discuss the details of these metrics and in Chapters 5 and 6 how to collect and control them.

3.3 THE EU CODE OF CONDUCT ON DATA CENTRES

Best practices

The EU Code of Conduct (CoC) aims to provide a 'light touch' but effective set of '*best practices*' to maximise data centre efficiency. The CoC is not a mandatory standard (See Chapter 8 for more on this), it is an attempt to develop and promote 'best practice' within the data centre community.

Endorsers

Participants

There are two categories of 'membership' of the CoC, *endorsers* – organizations which support the CoC via product manufacture, education etc. and *participants* – operators of data centres who wish to apply the CoC to their operation.

Through a well-defined process of measurement, assessment and improvement, supported by ongoing monitoring, it should be possible to ensure that the data centre is performing as efficiently as possible. A well-developed mechanism for sharing best practice within the data centre community, and a process of ongoing audit is included.

Participant

The initial phase of applying to be recognised as a *participant* of the CoC has been defined as a three-stage process:[88]

1 Provide one month's energy metering data
2 Audit compliance against 'appropriate' best practice
3 Implement any changes shown up by the audit

[88] http://www.gov.mu/portal/sites/GreenIT/downloads/DataCenter_CodeOfConduct_Introductory_Guide.pdf

Step 1 requires a preliminary assessment of the energy metering capability, and each step also requires data entry into the spreadsheet provided – this forms the supporting evidence for the application to be recognized as working within the CoC.

Following acceptance as a participant, it is required to submit an annual update, providing evidence that the data centre's operation continues to meet the CoC.

SUMMARY

In section 1 we discussed Carbon Trading and the Enhanced Greenhouse Effect.
In section 2 we gave an overview of Greening of ICT and Greening by ICT.
In section 3 we discussed the energy consumption and efficiency opportunities of a data centre, the metrics and the best practices according the CoC (Code of Conduct on Data Centres).

MODEL ANSWERS

1 Answers to Reflection Questions

1 The impact of Greenhouse Gases on our environments is:
i Enhanced greenhouse effect which leads to a higher than normal average temperatures of the earth which would lead to a climate change that could cause disastrous consequences as discussed in Section 1.1.2.
ii Carbon Cycle and enhanced greenhouse effect – if all of the CO_2 released through natural processes and human activities cannot be absorbed back into the carbon cycle by land and oceans, then the overall amount of CO_2 in the atmosphere increases. This results in an enhanced greenhouse effect in (i).

2 A global carbon cycle (adapted from here[89]) and is also shown in Figures 2 and 3. The earth is a system which contains the following components:
i Carbon Pools - sometimes also called stocks or reservoirs) because they act as storage houses for large amounts of carbon. They are: the earth's crust, ocean, and the atmosphere;
ii Carbon Flux - movement of carbon between these reservoirs and fluxes connect the reservoirs together. Examples of carbon fluxes are: photosynthesis, respiration (plant, human, animal, etc.), litter fall, human activities, oceans-atmosphere exchange.

The global carbon cycle is in a state of dynamic motion and if the amount of carbon moving into a given pool is matched by an equal amount of carbon moving out, the pool size remains constant. If this condition were true for all carbon pools, the global carbon cycle would be said to be in a state of dynamic equilibrium; 'dynamic' because the carbon itself is moving, and 'equilibrium' because the equal size of all inputs and outputs keeps the system in balance. The size of all carbon pools remains unchanged.

3 The causes of a climate change are listed in answers for Reflection 1. The effects of a climate change have been discussed in Section 1.1.2

4 Global collective efforts on mitigating the effects of climate change are:
i Signing of the Kyoto Protocol (Section 1.1.3)
ii Greening of ICT and Greening by ICT (Section 2)

5 i Increased energy consumption
ii Environmental impact due to: increased greenhouse gases emissions; e-waste; depletion of physical resources used for the manufacture of ICT equipment.

6 According to the Smarter2020 report, a decreasing growth rate in the CO_2 emissions in the ICT industry is due to: energy efficiency gains in end-user devices (e.g. laptops, tablets, pcs, etc.), telecommunication networks, and data centers; use ICT to deliver green commitments, and efficient, green business practices.

[89] http://globecarboncycle.unh.edu/CarbonCycleBackground.pdf

7 By 2020 the wireless networks emission growth rate is expected to surpass that of the wired networks because of: increase in the number of mobile subscriptions; data usage per user will increase due to increase of data-intensive services and applications (e.g. music and video streaming) adopted by smartphone and tablet users.

8 Data center emissions growth rate will be highest compared to end-user devices and networks because of: increase in the demand for data storage.

9 Energy is produced by burning fossil or carbon-based fuels (e.g. coal, oil, wood, etc.) as a result of this combustion, GHG are produced and released to the atmosphere. Thus, an increase in energy consumption (of this source) will result in an increase of GHG emissions.

10 E-waste is defined as 'any refuse created by discarded electronic devices and components as well as substances involved in their manufacture or use'[90].
Ways to reduce e-waste are:, recovery, reuse and recycling.

12 ICT water footprinting is important because fresh water is scarce.

13 ICT impact on climate change could be mitigated through 'Greening of ICT' and 'Greening by ICT' (See Section 2.1).

14 Look at Figure 15.

15 The ENERGY STAR program is a US EPA voluntary program that promotes energy savings and efficiency in ICT products. Products can earn the ENERGY STAR label by meeting the energy efficiency requirements set forth in ENERGY STAR product specifications.

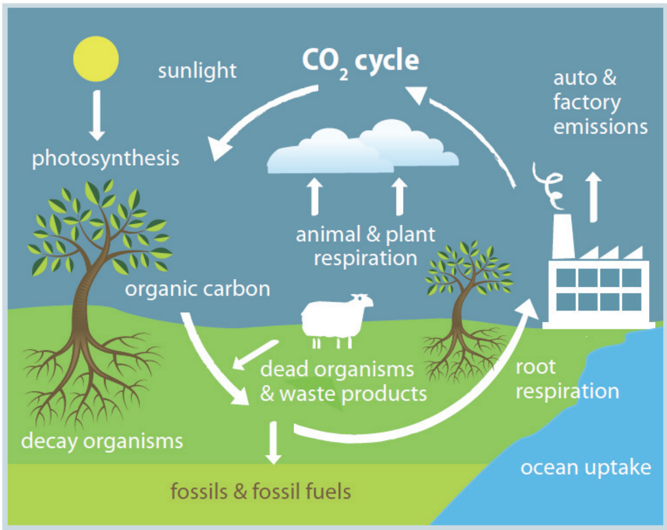
16 The differences between EPEAT and the ENERGY STAR are[91]:
1 ENERGY STAR covers energy efficiency. EPEAT is a more comprehensive measure of reduced environmental impact than ENERGY STAR.
2 EPEAT's environmental criteria cover the complete product lifecycle. EPEAT-registered products meet anywhere from 21-42 other rigorous criteria in addition to the latest Energy Star standard.

17 Other ecolabels can be found in this website:
http://www.ecolabelindex.com/ecolabels/?st=category,energy

[90] http://searchdatacenter.techtarget.com/definition/e-waste
[91] http://www.epeat.net/documents/purchaser-resources/EPEAT_Basics_Preso_12%200710.pdf

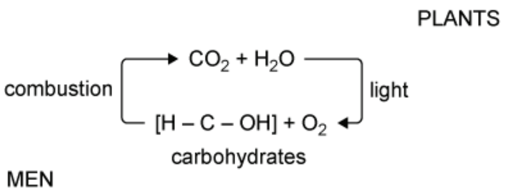
2 Answers to Tasks

2 A Simple Carbon Cycle



Extracted from:
http://sfrc.ufl.edu/extension/ee/woodenergy/files/activities/WoodEnergy_activity2.pdf

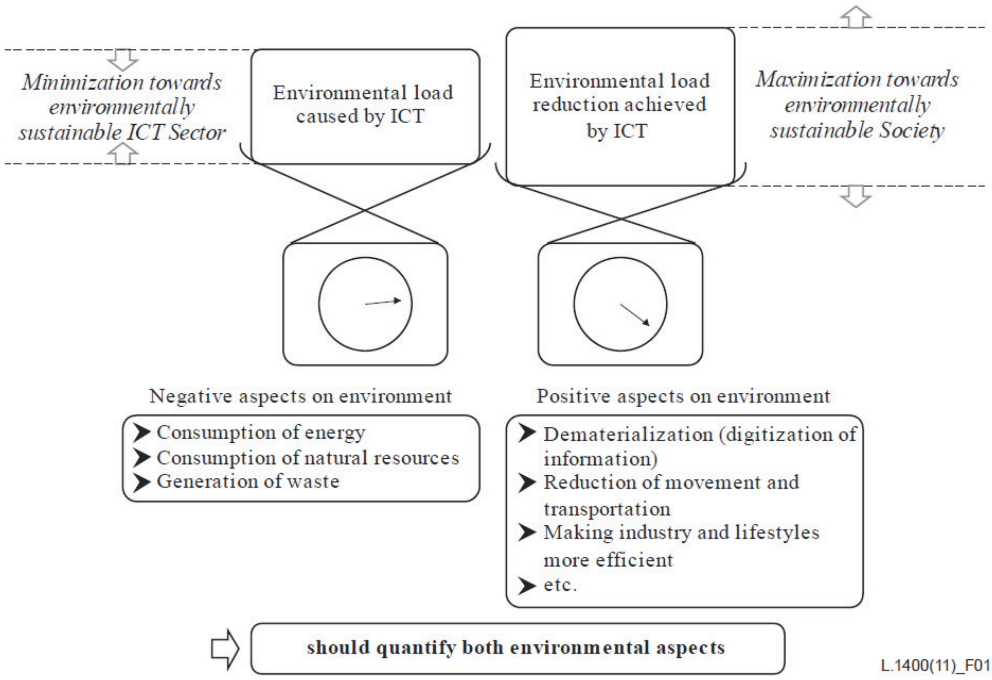
A very simple, but chemically correct cycle is:



7 Definition of e-waste by the UK Environmental Agency "If an item of EEE (electrical and electronic equipment) has been discarded by the holder into any waste collection system, it will become WEEE (Waste Electrical and Electronic Equipment)".

Definition of e-waste by WEEE Directive 2003
WEEE means electrical or electronic equipment which is considered waste when the holder discards or intends or is required to discard it. It includes all components, subassemblies and consumables which are part of the product at the time of discarding.

8



The list can be generated based on the diagram below[92]

14 Comparison between EPEAT and ENERGY STAR[93]

ENERGY STAR	ENERGY STAR® is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping save money and protect the environment through energy efficient products and practices. http://www.energystar.gov
Products	**Criteria**
• Appliances • Computers & Electronics • Heating & Cooling • Lighting & Fans • Plumbing • Building Products	• Must meet stringent requirements for estimated annual energy consumption • Must deliver same or better performance as comparable models

[92] http://www.itu.int/rec/T-REC-L.1400-201102-I
[93] http://sustainability.psu.edu/sites/default/files/images/EPEATvsEnergyStar.pdf

EPEAT® goes beyond energy savings

In addition to the requirement to meet the most recent ENERGY STAR standard, EPEAT registered products are also evaluated in relation to 23 mandatory and 28 optional environmental criteria. To qualify for registration as an EPEAT product, the product must confirm to all the required criteria. http://www.epeat.net

Products

- Desktop computers
- Laptop computers
- Thin Clients
- Workstations
- Computer Monitors

Criteria Categories

- Reduction/elimination of environmentally sensitive materials (cadmium, lead, mercury, etc.)
- Materials selection (recycled content)
- Design for end of life (disassembly, recyclable)
- Product longevity/life cycle extension
- Energy conservation (ENERGY STAR)
- End of life management (take-back service)
- Corporate performance
- Packaging (recyclable, reduction of toxics)

EPEAT BRONZE	EPEAT SILVER	EPEAT GOLD
Meets all 23 required criteria	Meets all 23 required criteria plus at least 50% of the optional criteria	Meets all 23 required criteria plus at least 75% of the optional criteria