Introduction

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As information and communications technologies (ICTs) have become more widespread they have, certainly in more developed nations, become "invisible"; we don't see them because we just accept they are there – often we only understand their significance to our lives when they break down. When only a few people had these gadgets they were novel, but as they became more common, and were eventually assimilated to become part of our modern culture, they became transparent; they're just another part of our everyday life. The implicit association of these technologies with a "modern" lifestyle has in turn become a driver for their adoption in less developed states.

To understand the sustainability of ICTs we must look at the life cycle[1] of the devices themselves, from the sources of raw materials, through production, use, and finally disposal. The ever greater use of ICTs is taking place within a finite environmental system, and that system, like the human system in general, has limits.[2] There are serious questions about how long we will be able to sustainably use today's high-speed digital technologies before the "ecological limits" on production make them either too rare,[3] or too costly, to justify their use as just another "invisible" element of our mass consumption culture.

The greatest technological breakthrough of modern electronics has been the ability of a simple programmable device to perform a wide variety of different functions. This is the true meaning of the term "convergence":[4] rather than having to have many specialised devices we can now use one multi-functional device programmed to undertake different operations. The fact that all these devices are based on the same basic components – at the simplest level they're an assembly of many millions of transistors – means that they are all reliant on the same raw materials for their production. It's not the silicon of the "silicon chip" that's the problem. Silicon is a plentiful mineral, although it does take large quantities of energy to make the very pure silicon required to produce the latest high-speed microprocessors and memory chips. The difficulty is the minute quantities of other rarer metals[5] – such as indium, hafnium, germanium and gallium – that the silicon is combined with to create the unique properties required for a microchip, a memory chip or an imaging device. Although only minute quantities are used in each chip, and even though many more chips are now produced, the critical limitation is that these minerals occur in only a few places around the globe. Some governments are now arguing for strategic policies to protect the supply of these "critical raw materials"[6] and ensure access to these resources in the future. An aspect of the limited supply of these critical materials is that, as scarcity makes prices rise, the shortage of supply is an incentive to their illicit production.

Another important metal in the production of miniaturised digital electronics is tantalum. Half of the world's tantalum supply is mined in Australia, and it is produced as a by-product of other metal mining operations in many states, but between 1% and 10% may be mined illegally in central Africa. This trade in turn supplies the finance that perpetuates the armed conflict[7] in these areas, and the human rights abuses that are the result.[8]

It is not just rare metals that are becoming problematic. There has been much discussion over recent years about "peak oil"[9] – the principle that global oil production will reach a peak of supply and then decline,[10] with dire economic consequences for the globe when this takes place.[11] Theoretically other minerals too can reach peak production,[12] and another metal vital to digital electronics may have reached its production peak: *gold*.[13] As a result of restricted supply, gold prices have remained high and so in many places around the world we now see illegal gold mining taking place – such

1 Leonard, A. (2010) *The Story of Stuff*, Constable, UK; Leonard, A./Free Range Studios (2008) *The Story of Stuff with Annie Leonard*. www.storyofstuff.com

2 Meadows, D. (2004) *Limits to Growth: The 30 Year Update*, Earthscan; Turner, G. (2008) *A Comparison of The Limits to Growth with Thirty Years of Reality: Interim Report*, CSIRO, Australia. www.fraw.org.uk/files/peakoil/csiro_2008.pdf

3 Cohen, D. (2007) Earth Audit, *New Scientist*, No. 2605, 23 May, p. 34-41. www.newscientist.com/article/mg19426051.200-earths-natural-wealth-an-audit.html

4 Wikipedia, *Technological Convergence*. en.wikipedia.org/wiki/Technological_convergence

5 Mobbs, P. (2010) *Limits to Technology – Annotated Presentation Slides*, Free Range Network. www.fraw.org.uk/workshops/limits_to_tech/virtual_presentation.shtml

6 European Commission (2010) *Critical raw materials for the EU*, CEC. ec.europa.eu/enterprise/policies/raw-materials/files/docs/report_en.pdf

7 Global Witness (2009) *Faced with a Gun, What Can You Do?* www.globalwitness.org/media_library_get.php/980/1277197135/report_en_final.pdf

8 Sourt, C. (2008) The Congo's Blood Metals, *The Guardian*, 26 December. www.guardian.co.uk/commentisfree/2008/dec/25/congo-coltan

9 Wikipedia, *Peak Oil*. en.wikipedia.org/wiki/Peak_oil

10 Mobbs, P. (2005) *Energy Beyond Oil*, Matador, UK.

11 Froggatt, A. and Lahn, G. (2010) *Sustainable Energy Security: Strategic risks and opportunities for business*, Lloyds/Chatham House, UK. www.chathamhouse.org.uk/files/16720_0610_froggatt_lahn.pdf

12 Bardi, U. and Pagani, M. (2007) Peak Minerals, *The Oil Drum Europe*, 15 October. www.theoildrum.com/node/3086

13 Evans-Pritchard, A. (2009) Barrick shuts hedge book as world gold supply runs out, *The Telegraph*, 11 November. www.telegraph.co.uk/finance/newsbysector/industry/mining/6546579/Barrick-shuts-hedge-book-as-world-gold-supply-runs-out.html

as in Nigeria, where the environmental pollution created by unregulated gold processing has killed over 100 children.[14]

Next let's consider manufacturing. As with most of the high-volume manufacturing capacity of the globe, a large proportion of the world's high-tech consumer goods are now produced in Asia – China in particular. Asian nations have received much criticism for their lax controls over the production of shoes and clothing in large "sweat shop" factories, but we see a similar style of operation used in the production of electronic consumer goods – albeit within the clean room environment required for the production of microelectronics. While workers in these facilities will receive pay and benefits that are higher than in other types of industry in the region, and so jobs in these factories are in high demand, the psychological pressures of working within this environment are often as high as conventional production facilities. This issue has received coverage recently following the suicide of workers involved in the production of iPods for Apple.[15]

Within electronics production generally the chemicals and materials that are an essential part of the process have implications both for the safety of production workers and the well-being of the local environment.[16] From the hazardous solvents to neurotoxic flame-retardant chemicals, the production of consumer electronics is potentially a very hazardous operation for those involved. As well as the direct hazards during production, the emissions from factories, and from local waste management facilities, can pollute the local environment, soils and water supplies.[17] It can take many years for the slow accumulation of such toxins to take effect, especially the persistent organic pollutants used in many different electronic components, so the overall impact of the recent development of high-tech manufacturing in Asia may not be apparent for some time.

With the rising concern about climate change there is an increasing focus on the amount of electricity that ICTs consume. The more gadgets we have, especially mobile devices that require charging, the greater the demand for electricity.[18] At present, around the globe, the fuel being used to meet much of the demand for new electricity generation is the worst from the point of view of carbon emissions: coal. However, it's not the everyday use of ICTs that's driving their electricity demand.

Though people might focus on the direct use of electricity by devices – because that's the part of the system they can "see" – in terms of the overall life cycle of ICT devices, more energy will have been used during their production. In fact, as the direct energy use of electrical goods reduces, so the energy consumed in production becomes more significant.[19] For example, the memory chip in a laptop computer can take more energy to produce than the laptop itself will consume over its three-year service life.[20] Another example is video display screens where, although the older glass cathode ray displays consume more electricity while in use, the newer flat panel displays require far more energy to be expended during production.[21]

The debate over "green ICTs" demonstrates the complexity of this issue – and the importance of defining our terms and boundaries for measuring impacts. As in the example above, if we simply compare the energy consumption of an old glass cathode ray display to a new flat panel display we are not going to produce a valid impression of the ecological impact, because the bulk of the energy consumption for digital electronics tends to be during the production, not in everyday use.[22] The concentration on carbon emissions is also a distraction as, irrespective of the energy sources used in the manufacturing process, one of the most pressing problems for the future of ICTs is a shortage of the critical raw materials used in their production. Once the most productive sources of these materials are exhausted, which (in the case of metals such as indium or gallium used in flat screen displays) may be only in two or three decades time, the use of these technologies will be restricted too.

14 Yahaya, S. (2010) Nigeria tries to end "gold rush" after child deaths, *Reuters*, 9 June. www.reuters.com/article/idUSTRE6581VD20100609

15 Branigan, T. (2010) Tenth apparent suicide at Foxconn iPhone factory in China, *The Guardian*, 28 May. www.guardian.co.uk/world/2010/may/27/foxconn-suicide-tenth-iphone-china

16 Silicon Valley Toxics Coalition (n.d) *Electronics Industry: A Dazzling Industry With a Dark Side*. www.svtc.org/site/PageServer?pagename=svtc_electronic_industry_overview

17 Brigden, K., Labunska, I., Santillo, D. and Walters, A. (2007) *Cutting Edge Contamination*, Greenpeace. www.greenpeace.org/raw/content/usa/press-center/reports4/cutting-edge-contamination-a.pdf

18 International Energy Agency (2009) *Gadgets and Gigawatts*, OECD/IEA, Paris; *Gadgets and Gigawatts: Summary*. www.iea.org/Textbase/npsum/Gigawatts2009SUM.pdf

19 Williams, E., Ayres, R. and Heller, M. (2002) The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices, *Environmental Science and Technology*, 36 (24), p. 5504-5510. www.it-environment.org/publications/1.7%20kg%20microchip.pdf

20 de Decker, K. (2009) The monster footprint of digital technology, *Low Tech Magazine*, 16 June. www.lowtechmagazine.com/2009/06/embodied-energy-of-digital-technology.html

21 Socolof, M., Overly, J. and Geibig, J. (2005) Environmental life-cycle impacts of CRT and LCD desktop computer displays, *Journal of Cleaner Production*, 13, p. 1281-1294.

22 Socolof, M., Overly, J., Kincaid, L. and Geibig, J. (2010) *Desktop Computer Displays: A Life-Cycle Assessment*, US Environmental Protection Agency, EPA-744-R-01-004. www.epa.gov/dfe/pubs/comp-dic/lca

This brings us to the issue of disposal and recycling. The conventional view of resource economists is that recycling extends the lifetime of a resource because we need not dig up as much raw material. Recent work on the ecological economics[23] of resource production shows that this is often not true, because the effect of growing consumption negates, to some extent, the effects of recycling and more efficient production – a process known as the "rebound effect".[24] For digital electronics the problem is more complex because the concentration of the critical raw materials within the electrical goods is in most cases less than their concentration in the natural environment, making reclamation of some resources practically impossible. For certain metals, such as gallium or indium, this means that recycling does not offer a way to significantly extend the life of these resources.

For other metals – such as gold, copper, silver and tin – recycling offers the best option to extend the lifetime of these resources. However, as most consumer electronics are not designed to be disassembled and efficiently recycled, the methods available to economically recover the materials they contain are often crude. In many developed states electrical goods are being banned from landfill disposal, so some sort of reclamation process is required to deal with electronic waste (e-waste). The commonest method to recycle electronics is to crush, fragment and burn them in order to recover the most valuable metals.[25] In developed nations this is done to high environmental standards in specially designed reclamation furnaces. However, the high cost of doing this means that a market has sprung up to ship used electronic goods to developing nations where they are processed using far less rigorous standards.[26] Often devices are manually broken apart to remove the most valuable components, and then much of what is left is burnt on open fires. This is creating a toxic legacy[27] that could last for many generations as the soil, groundwater and local rivers are contaminated with a cocktail of metals, partly burnt plastics and toxic chemicals.

There are ways to address many of these issues. However, they're not "business as usual", and for that reason they require some major institutional changes within the ICT industry. To make the diminishing level of critical raw materials last longer we need to extend the life of all electrical goods. At present digital electronics is only achieving a fraction of the lifetime that could be achieved if devices were designed for a longer life. The difficulty for the electronics industry is that longer life will lead to lower turnover, and that in turn means that the nations who have specialised in the mass production of electrical goods will grow more slowly. Another great step forward would be designing devices in ways that maximise recycling and reuse, and to remove as much of the toxic content of electrical goods as possible so that end-of-life reclamation does not create such toxic waste residues.

While making gadgets last longer has an impact on manufacturers, perhaps the greatest impact will be upon the software community. They too focus on short product lifetimes, planned obsolescence and restricting backwards compatibility to ensure that users must upgrade. However, this "culture of obsolescence" is predominantly the preserve of the proprietary software industry. In terms of the most sustainable life cycle for ICTs, open standards and open intellectual property are far more likely to lead to extended lifetimes because the pressures to continually upgrade are not so great. For this reason the free and open source software and fledgling open source hardware movements offer a greater potential to develop a more sustainable ICT industry.

In the end, this is a design issue: it is a matter of how we choose to build human systems. If we respect the physical boundaries to the natural world then we can make a truly sustainable culture. The difficulty is that recognising these limits inevitably means applying limits to ourselves. ■

23 Wikipedia, *Ecological Economics*. en.wikipedia.org/wiki/Ecological_economics

24 Sorrel, S. (2007) *The Rebound Effect*, Sussex Energy Group/UK Energy Research Centre. www.ukerc.ac.uk/Downloads/PDF/07/0710ReboundEffect/0710ReboundEffectReport.pdf

25 Sullivan, D. (2006) *Recycled Cell Phones: A Treasure Trove of Valuable Metals*, U.S. Geological Survey. pubs.usgs.gov/fs/2006/3097/fs2006-3097.pdf

26 Brigden, K., Labunska, I., Santillo, D. and Allsopp, M. (2005) *Recycling of Electronic Wastes in China and India: Workplace and Environmental Contamination*, Greenpeace International. www.greenpeace.org/raw/content/international/press/reports/recyclingelectronicwasteindiachinafull.pdf

27 Puckett, J. (2005) *The Digital Dump: Exporting Re-use and Abuse to Africa*, Basel Action Network. www.ban.org/BANreports/10-24-05/documents/TheDigitalDump_Print.pdf