Journal of Information, Communication and Ethics in Society

The clean side of slow tech: an overview:

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Invited Paper for Journal of Information, Communication & Ethics in Society (JICES)

The Clean Side of Slow Tech: An Overview

Abstract

Purpose - The need to rethink the impact of information and communication technologies (ICT) on people's lives and the survival of the planet is beginning to be addressed by a Slow Tech approach. Among Slow Tech's main questions are these two: Is ICT sustainable in the long term? What should be done by computer ethics scholars, computer professionals, policy makers, and society in general to ensure that clean ICT can be produced, used and appropriately disposed of?

Design/methodology/approach - The paper is based on a comprehensive review of clean tech-related literature and an investigation of progress made in the clean tech field.

Findings - This opening paper of a JICES special session aims provides an overview of clean ICT, including a brief review of recent developments in the field and a lengthy set of possible reading matter. As a result, it is anticipated that Slow Tech - and in this case, its second component of clean ICT - can provide a compass to steer research, development and the use and re-use of environmentally-friendly, sustainable ICT.

Originality/value - This conceptual paper emphasises that, until only recently, no-one questioned the potential long-term sustainability of ICT. This issue is, however, now very much a matter that is on the research and teaching, and action, agenda.

Keywords - Clean ICT, Green IT, Future ethics, ICT sustainability, Slow Tech.

Paper type - Conceptual paper.

1. Introduction

One of the most important messages with regard to the environment expressed over the last four decades, is that there are limits to growth - i.e., restrictions on those activities that can have an impact on the planet (Meadows et al., 1972). Unfortunately, this MIT report which resulted from the university's research on world systems dynamics (Forrester, 1971) was ignored for several decades.

Over the past 25 years, thanks to the expansion of the work of the Intergovernmental Panel on Climate Change (IPCC), awareness about climate change has re-emerged. Several of the panel's reports did not assist policy-makers to reach an agreement on the next actions to take. However, the 2014 update of the report urges all countries to reflect on the need to revise the model of industrial development that is currently followed: CO_2 has grown by 40% since the beginning of the industrial revolution and by 20% over the last 50 years. As a consequence, the average temperature of the planet has grown by 0.89 degrees centigrade, and sea levels have risen by 0.19 metres during the last century (IPCC, 2014). In response to the urgency of these kinds of figures, European Union leaders agreed on a new set of CO_2 emission lists as of 2030 (BBC News, 2014).

Over the same quarter of a century, philosophers (Jonas, 1979), future thinkers (Skrimshire, 2010), and researchers (Di Paola and Pellegrino, 2014) also began a profound rethink about technological development and its consequences for current and future generations. Indeed, they suggested that it is important to prepare for a future ethics that includes dramatic changes in societal and environmental scenarios. Even economists, one of those communities that is perhaps most stubborn with regard to the concept of limits and has a tendency to think in terms of exponential growth, have begun to discuss the concept of a "circular economy" (Stahel and Reday-Mulvey, 1981; EMAF, 2013).

In contrast, what about the ICT community and, in particular, those scholars and computer professionals who work in the field of computer ethics? What do people who question the ethics of technology have to say about the impact of ICT on the environment and long-term sustainability? These issues are already being treated by a welcome debate: a number of environmentally-related questions are starting to be addressed (e.g. Fairweather, 2011; Whitehouse et al., 2011; Hilty et al., 2011; Patrignani and Kavathatzopoulos, 2012). Since 2013, several conferences have taken place that are dedicated to ICT sustainability (for example, ICT4S, 2013; ICT4S, 2014). In the European Commission (Von Schomberg, 2011) and the European research community, interesting discussions about responsible research and innovation in ICT, that should also include environmental questions, have been launched (FRRIICT, 2014). A quest for a human-centric digital age is also growing (European Commission, 2014).

Querying the role of technology, in particular ICT, is becoming crucial in western societies from the points of view of human-centrism, sustainability and fairness. A Slow Tech approach (Patrignani and Whitehouse, 2014), an ICT that takes into account the limitations of human beings (good ICT), the limits of the planet (clean ICT), and the working conditions of personnel throughout the entire ICT supply-chain (fair ICT), is of fundamental importance to the future of this planet and its people. Indeed, the complexity of ecological challenges related to ICT and the environment are so serious that the debate should definitely be expanded and continued.

Further in-depth research on these questions is required over the next years. The precise questions to be posed need to relate to three fields: the production, use and disposal of ICT. The following three challenges can be cited as potential questions for action research:

- **Production**: When ICT is manufactured, will the materials needed to produce ICT hardware be available in the long-term?
- **Use**: ICT can act as a wise way for increasing the process of de-materialisation (that is, moving from paper to electronic communications) and reducing pollution: however, what are its side effects on the environment? Given that ICT can foster the transition to a less material-intensive economy (Hilty, 2008) - because that transition may take centuries - is the long-term availability of ICT realistic? As a specific example, what will be the impact of cloud computing's gigantic data centres on the environment?
- **Disposal**: How can the growing mountains of ICT *e*-waste be handled?

2. Clean ICT

There are several forms of research and application taking place in the clean ICT field, such as ICT sustainability, sustainable development and green ICT/information technology (IT).

Until relatively recently, ICT was widely accepted as being good for the environment. Over the past decade, research on ICT sustainability has begun (e.g., Kuhndt et al., 2006) that incorporates the challenging goal of demonstrating ICT goodness. However, this goodness can be difficult to show precisely. Meanwhile, green ICT has set about investigating the connectivity between information technology and the environment. While green ICT can be criticised for having addressed certain limited questions, for example, the power consumption of data centres or the selection of renewable power sources (Curry et al., 2012), it has nevertheless produced interesting design guidelines for the reduction of energy supply (O'Neil, 2010). In addition, sustainable development is aiming to "*... meet[s] the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987).

According to the Slow Food movement, clean food implies food whose production or consumption does not harm the environment, animal welfare, or humans and their health (Petrini, 2007). By extension, clean ICT focuses on avoiding harm to precisely the same three entities of the environment, animal welfare and human health. Clean ICT means developing computer systems and networks that are respectful of these three entities as a result of considering them as actual stakeholders in the global system (Freeman and Moutchnik, 2013).

More ambitiously, the clean ICT concept aims at addressing the entire production chain or life-cycle of ICT products and services.

Slow Tech itself focuses on what it calls in-depth "probes", i.e. investigations or inquiries. From the production, to the application and the disposal of ICT, probes are needed to help investigate and measure the environmental impact of ICT. The results of these investigations can then be used for at least three purposes: to reduce environmental impact, to re-think the sustainability of ICT, and to reconsider seriously ICT consumption cycles and their speed. Considerations to bear in mind are discussed in the remainder of the sub-section of this paper: material consumption in the production phase of ICT; power consumption during the application and use of technology phase; and the considerable damage that ICT can do to the environment during its disposal.

Producing ICT

As with any other physical process, the materials used to produce ICT devices imply a

decrease in the energy availability in the future. As a consequence, there are several future possibilities relating to the production of goods. Not only does energy degrade at every stage of transformation (due to the law of entropy), but the availability of materials also decreases (thus provoking the expression that "*matter matters too*" (Georgescu-Roegen, 1979)). Once extracted from underground and dispersed into the environment, many raw materials can be reused only in decreasing quantities and at increasing economic cost (Georgescu-Roegen, 1971; Bardi, 2014). Both the cleanliness of hardware production processes and the material intensity of microprocessors are being assessed from a sustainability point of view: for example, in 2010 a study by Yale University researchers showed that "*... the increasingly use and mining of rare metals, can have devastating environmental consequences as well as serious geo-political concerns*" (Schmitz and Graedel, 2010).
The physical process for producing microchips on silicon has one of the highest "material intensities" in the whole industry. For memory chips the ratio is 1:850, i.e. to produce a chip that weighs one gram, 850 grams of chemicals and fossils fuel are necessary. For microprocessor chips, the ratio is much higher: it is 1:3440 (SVTC, 2007). Minerals like cobalt, copper, gold, tin and tungsten are fundamental to the electronics industry. Their mining and use are now being tracked by international organisations, which are discovering that many modern technologies and devices contain minerals extracted through child labour, and forced labour and slavery (Nimbalker et al., 2014). The materials used to produce chips include a quantity of rare earths that are, by their very definition, limited resources. One of the most famous examples of a material used in the majority of today's ICT devices is coltan (a columbium-tantalum mineral). Coltan is extracted through mineral mining activities in countries such as the Congo, extraction that is often performed by children in conditions of illegality (Vazquez-Figueroa, 2010).

Using ICT

Of course, ICT needs to be powered in order to function. The difficult challenge is the resulting energy balance. By using ICT, energy is saved as a result of the improvement in the efficiency of the implicit processes, but does the energy saved counterbalance that consumed in the manufacturing, use, and disposal of the technologies? For example, the energy used in powering ICT, like the gigantic data centres of the cloud computing era, doubles every five years (Uddin and Rahman, 2010; Rowe et al., 2011). By the end of 2013, the number of potential users accessing the cloud was more than 2.8 billion (IWS, 2014). These consumers use devices that need to be powered to operate, without also calculating the power consumption of the electronic network itself (Karendra et al., 2014). As a consequence, the CO_2 emissions related to ICT - those green-house gases that affect climate change - today are at around the same level of those identified as being emitted by the airline industry (Fettweis and Zimmermann, 2008; European Commission, 2012).
According to one of the most recent and comprehensive studies on the total energy balance of ICT, the emissions due to ICT are estimated to reach by 2020 1.27 Gigatonnes of carbon dioxide ($GtCO_2$) through the number of "end user devices" (53%), "voice and data networks" (24%), and "data centres" (23%). By the same date, ICT is said to reduce emissions by 9.1 Gigatonnes of carbon dioxide equivalent ($GtCO_2e$). This is considered to occur through "process, activity and functional optimization" (44%), "system integration" (25%), "data collection and communication" (25%), and "digitalization and dematerialization" (6%): this is known as abatement potential (GESI, 2012). Therefore, it looks as though the ICT energy balance is positive: the savings in CO_2 due to ICT application to society's activities are seven times more than its contribution to CO_2. Nevertheless, a number of issues need further research: for example, how can the contribution in carbon dioxide equivalent to the activities needed to build ICT and to manage *e*-waste be calculated?
These fundamental questions with regard to the use of ICT mean focusing on the three sets of challenges mentioned earlier: first, an appreciation of the limits of the planet; second, the need to take into consideration the entire ICT life cycle (producing, using, and disposing of ICT); and, third, a questioning of the extent of the consumer ICT life cycles that finite materials can support.

Disposing of ICT

From some radical points of view, *e*-waste - the overall volume of discarded electronic devices - is not an aberration or an extreme case, it is embedded in the surplus produced by capital: the information age is therefore inherently toxic (Enright, 2011). In the meantime, it is worthwhile investigating possible directions for addressing the problem of toxic electronic waste disposal. Hazardous substances like cadmium, chromium, lead and mercury are contained in many ICT products: therefore, the related environmental risks of disposal are perceived as being very high (Greenpeace, 2012).

Clean ICT means investigating the destination of hardware devices at the end of their life. Unfortunately, the precise location of *e*-waste disposal is not always known. The majority of *e*-waste products are sent to destinations where their treatment process is questionable. The problems related to *e*-waste have reached broadcasting headlines in recent years. Published by the Blacksmith Institute and Green Cross Switzerland, a 2013 report about the top ten most polluted places in the world puts the Agbogbloshie dumpsite in Accra, Ghana in pole position. Agbogbloshie forms an immense mountain of electronic devices that have been disposed of mainly by western countries: every year, the pile grows by about 215,000 tons (Bernhardt and Gysi, 2013). In 2014 *The Economist* magazine underlined the need for a fairer way to manage ICT waste: "... *A growing mountain of electronic waste needs to be disposed of responsibly by rich nations rather than shipped to poorer countries to do the dirty work*" (The Economist, 2014).

There are various possible solutions to the handling of *e*-waste: here, we cite three that can be incorporated in a clean ICT approach. First, for example, there is ICT recycling; for example, gold can be extracted from old computers and then be recycled with approximately the same level of inconvenience as mining the mineral in the first place (Step, 2013). Unfortunately a real ICT recycling process is not yet in place. There are just a handful of attempts to extract some value from *e*-waste, such as those undertaken by Umicore (Umicore, 2014). However, this is extremely dangerous work for both human beings and the environment. When this kind of recycling is undertaken in the United States of America, it costs ten times more to do than in China: this explains why, in the early years of this century, an estimated 80% of all ICT waste was being sent to Asia (Puckett and Smith, 2002). Second, another possible direction is to approach the problem before the actual manufacturing of ICT begins, at the design stage. If devices can be easily repaired, then their lives could be lengthened. However, this requires a recyclable-by-design approach - an approach in which all the interfaces among interoperable modules are open, all components are described in detail, and anyone can contribute to the innovation process. Examples of already functioning approaches include those from the open hardware or free software industries (Arduino, 2014; FSF, 2014) and, more specifically, recent approaches to the design and construction of smart phones, whether via individual designers, social enterprises or large-scale corporations such as Google and Motorola (Fairphone, 2014; Phone-blok, 2014). Third, more comprehensive approaches to new industrial products development, such as "cradle-to-cradle", or "regenerative design", illustrate attempts to learn from natural cycles (Lovins, 2008). These approaches aim at creating systems that are essentially waste-free: they view industry not as a mechanism but as an organism in which materials are the circulating nutrients. Taking such a view, industry should protect these nutrients in order to ensure healthy organisms (McDonough and Braungart, 2002).

3. Possible directions for Clean ICT

Clean ICT is difficult to undertake, but not impossible. Moving towards a clean form of ICT is strongly connected to involving all the relevant stakeholders in ICT: vendors, policy makers, users, and society in general with regard to ICT's ultimate outcomes and impacts.

For policy makers, for example, the kinds of questions to be posed are: What are or could be the new regulatory or consumer policies for clean ICT? What are the best standards for a recyclable-by-design ICT? How can the production be avoided of so-called "monolithic" devices that make maintenance impossible? How could the interoperability and easy repair of devices be facilitated?

Many efforts are currently on-going in the direction of clean ICT. Many of them, however, imply higher costs for the end product. Today's electronic devices are usually cheap, precisely because their cost does not include a considerable number of externalities. That is, these devices are not clean with respect to the environment, nor fair with respect to the workers who produce them and, ultimately, customers are not charged for the harm that the producer does.

So, would consumers be ready to pay more for clean ICT? Some good news shows that consumers' sensibilities are changing: an international study demonstrates that, in the three years from 2011 to 2014, the percentage of users willing to pay extra for products and

services from companies committed to positive social and environmental impacts has increased from 45% to 55% (Nielsen, 2014). What is particularly positive is that the highest percentage of these consumers comes from among the millennial generation (young people aged 21-34).
Last but not least, how can universities prepare the next generation of engineers capable of designing clean ICT? Even if the idea can be counterintuitive, software can have an impact on the environment. Researchers are studying how the power consumption of central processing units changes with the use of different programming styles (Kern et al., 2013). Therefore, too, in several software programming courses, programming styles are being presented as a possible contribution to encouraging clean ICT.

4. Discussion and conclusions

Currently under investigation is the question of whether a green economy can operate, or can be extended, under today's market-driven and short-term view of capitalism: rather, Klein suggests that the climate change crisis is needed so as to spur on transformational political changes (Klein, 2014). Such transformations are potentially underway, based on a longer-term view of the potential impacts of climate change (BBC News, 2014). Even the most prestigious business schools are now questioning the traditional vision of an economy perceived as a "*cold and heartless system*" that operates outside of human control: they claim that the economy can and should have a purpose, by providing goods and services for human well-being (Nelson, 2006). The myth of the maximisation of shareholder value as the sole mission of companies is being scrutinised by corporate experts: they demonstrate that concentrating on the mantra of the short-term can damage companies and their reputations, since managers are pushed towards irresponsible corporate behaviour (Stout, 2012).
If such new policy, research and teaching approaches are queried, there are many other ensuing dilemmas which require exploration. A tentative list of questions follows that form a good basis for further action research over the next years. The answers to these questions are left purposely open so as to stimulate future debate. For example:

- Can clean ICT be produced, used and disposed of within a market-driven economic scenario?
- Will the urgency of climate change force researchers to propose actions that are more reachable and do-able in the shorter term, accepting even partial results in such a context? Or is there sufficient time left for a global political change on clean ICT?
- Can consumers continue with their rush to accumulate material goods, including ICT?
- Can ICT vendors push indefinitely for fashionable, new devices that are focused only on short-term profits, and hence are promoted as being replaceable even on a month-by-month basis?
- Can clean ICT be achieved without questioning the increasing speed of people's current lives, and without examining the short-term view of most of the companies in the ICT market?
- How can all the actors in the ICT stakeholders' network be involved in committing themselves to the shared value of leaving a liveable planet for future generations?

This opening paper of a JICES special issue aims provides an overview of clean ICT. It includes a brief review of recent developments in the field and a comprehensive set of relevant reading materials. As a result, it is anticipated that Slow Tech - and in this case, its second element, clean ICT - can provide a compass to steer research, development and the use and re-use of environmentally-friendly, sustainable ICT.

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