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Abstract

Purpose – The purpose of this paper is to discuss the role of information and communication technology (ICT) for promoting environmental sustainability in a changing society. Isolated studies exist, but few take a holistic view. Derived from a Marxian tradition, the authors propose Ecological World Systems Theory (WST) as a holistic framework to assess the environmental impact of ICT. The theory is adapted responding to theoretical critiques of absence of change, namely state-centrism and structuralism.

Design/methodology/approach – Theoretical study. Empirical examples derived from already published literature.

Findings – Ecological WST focuses on the unequal distribution of environmental degradation, sees technological development as a zero-sum game rather than cornucopia and holds that technology is often seen as a fetish in today's society. The findings are that popular discourses on ICT and sustainability are since the 1990s becoming increasingly cornucopian, while conditions in the ICT value chain are less cornucopian.

Research limitations/implications – Theoretical contributions to Marxian critiques of ICT, with more environmental focus than earlier Marxian critiques, for example Fuchs' work. Develop a theoretical framework for ICT and sustainability which could be compared with works of e.g. Hilty, Patrignani and Whitehouse. The work is mostly based on existing empirical studies, which is a limitation.

Practical implications – This theoretical framework implies that unequal environmental degradation in different parts of the world should be taken into account when assessing environmental impact, for example by means of LCA.

Social implications – The framework brings together questions of environmental effects of ICT and global justice.

Originality/value – The authors apply a rarely discussed theoretical framework to ICT and environmental sustainability. By doing this the authors suggest how the discourses and the value chain of ICT is intrinsically tied to the world system.

Keywords Green computing/Green IT, Socio-technical theory, Literature review, Power, Critical theory, Theory building

Paper type Conceptual paper

1. Introduction

Concurrent with the increasing penetration of information and communication technologies (ICTs), society is changing. The ubiquitousness of ICT in society has lead to intense debate about ethical issues. In the light of environmental concerns, such as global warming, ICT is also discussed in relation to environmental sustainability. ICT is said to account for approximately 2 per cent of the world's total CO_2 emissions – in parity with the global airlines (Mingay, 2007).

There are several environmental implications related to the ICT sector to take into consideration, such as the production of electronic waste (e-waste), the extraction of rare earth elements (REEs) and the hazardous production of ICT equipment. Another important aspect is the energy usage of the equipment. Large data centers around the

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globe consume a considerable amount of the energy produced world-wide every year, and as ICT is getting increasingly mobile, mobile data traffic will pose an even larger threat for the environment than the data centres in the future (ECC, 2011). A recent report from Cisco (2015) suggests that global mobile data traffic will increase nearly 10-fold between 2014 and 2019, with increased energy use and environmental effects as results.

However, it has been suggested that ICT solutions also have great potential in improving the environment by mitigating the environmental impact of other energy consuming processes such as production, agriculture and transportation (GeSI, 2012). According to reports, Smart ICT solutions will potentially be able to decrease the annual greenhouse gas (GHG) emissions by 9.1 $GtCO_2e$ worldwide, as well as creating 29.5 million jobs and save 1.9 trillion USD for consumers and businesses (ibid).

Given this dualistic view on ICT presented above, how should one assess the environmental impact of ICT? Although there are many good isolated studies of real environmental impact of ICT devices, most often by means of life-cycle analysis (Malmodin *et al.*, 2010), there is a lack of holistic analyses of ICTs and the environment, inspired by philosophy, ethics and social sciences (see Fairweather, 2011; Lennerfors, 2014). Responding to the call for papers, we maintain that such holistic analyses are necessary in order to understand the role of ICT in a changing society. Isolated studies are necessary pieces in this endeavour, but not sufficient.

In critical studies of ICT, there are those who also question the isolation and fragmentation of scholarly and political discourse regarding the promotion of a sustainable society. Verdegem and Fuchs (2013) state that "discourses (of a sustainable society) are […] fragmented and lack a theoretical foundation that attempts to provide concise definitions of the categories in use" (p. 4). In response to this isolation, fragmentation and lack of theoretical foundations, Fuchs is inspired by a Marxian framework to holistically analyze the role of ICT. While Marxism might seem outdated to some, due to rising gaps between rich and poor caused by 35 years of neoliberalism combined "with the new global crisis of capitalism, we seem to have entered new Marxian times" (Fuchs and Mosco, 2012, p. 1). Partly inspired by Fuchs' work, our paper is also based on a Marxian framework, namely World Systems Theory (WST).

Developing Marxian studies of ICT beyond Fuchs' work, one conclusion drawn in this paper is that ecological World Systems Theory (Hornborg, 2011; Hornborg and Jorgensen, 2010; Hopkins *et al.*, 1982) could be a holistic framework with which one could assess the environmental effects of ICT. The paper also pays particular heed to the concept of change. WST has been critiqued for being too static and constant, and it is described how ecological WST could be adapted to fit into today's rapidly changing society.

In the second part of the paper Fuchs' work on ICT is discussed. Here, ecological WST is presented, developed and applied to ICT. The third part of the paper is divided into two sections corresponding to the Marxian concepts of base and superstructure. The popular, cultural discourses of ICT and sustainability are discussed under the superstructure. Regarding the base, examples from already published literature on unequal environmental degradation in the ICT value chain are presented. In the fourth part, the paper is concluded by a discussion of the implications of our approach in relation to non-Marxian studies of ICT and sustainability.

2. From Marxian critiques of ICT to ecological WST

This section is divided into three subsections. In the first one, ecological WST is discussed in relation to the Marxian critique of ICT proposed by Christian Fuchs. In the second subsection, ecological WST is discussed alongside with the critics of WST and an understanding of the potential for ecological WST is developed. In the third subsection, already existing work on WST and ICT is reviewed, while arguments for more research within this stream of research are presented.

2.1 Marxian critiques of ICT

Even though there are relatively few Marxian studies on the environmental effects of the ICT sector compared to many other fields, some important works have been identified. Christian Fuchs (2006, 2008) argues that ICT can have both positive and negative impacts on sustainability as well as on most other aspects of the society (Fuchs, 2006). For example, while ICTs allow the reduction of travelling by communicating online, equipment must not only be produced and later disposed of, which has environmental implications. Also, he draws the conclusion that ICTs do not decrease the need to travel and that people working from home often travel more than the conventional workers. Fuchs also argues that ICT allegedly leads to dematerialization of processes, which leads to a reduced usage of resources. However, using e-commerce as an example, he concludes that the potential of ICTs as means of sustainability is probably small even within this area (Fuchs, 2008).

Fuchs and Horak (2008) deconstruct James' (2003) argument that the exportation of old hardware from developed countries to more peripheral areas of the world is one way of closing the global divide. James (2003) suggest the lifetime of a computer in Western parts of the world is two to three years, while the same computer can be used for several years more in developing parts of the world. Fuchs and Horak, however, argue that the danger of exporting old computers to developing countries is that these countries have no efficient way of handling the inevitable disposal of the equipment. Furthermore, they argue that developing countries should have the same right to first-class ICT equipment as the developed world and suggests that in order to close the digital divide between core and periphery, the developing world must be allowed to enjoy the advantages of efficient ICT equipment. But because the digital divide is not mainly an environmental or technological problem, but a social, economical and political issue these problems cannot be solved by focusing solely on the technology. Fuchs eschews environmental and technological issues by stating that the digital divide is instead an expression of a larger divide in wealth and power, which should be solved by first of all cancelling all debts to developing countries while increasing development aid and providing free education and health care.

In the review of Fuchs' work on sustainability, it seems that it mostly concentrates sustainability into a social dimension, which is given predominance, epitomized in this sentence: "If humankind is interested in a sustainable society, the destructive character of the economy must be sublated, new models of economic production and social relationships are needed" (Fuchs, 2008, p. 308). Yet, in the very same papers Fuchs theoretically recognizes the interrelations between different dimensions of sustainability. Fuchs (2010) holds that sustainability is a very broad concept which should not be boiled down to environmental, economic, political, cultural or technological issues alone, but pay attention to the interrelated nature of these dimensions. In Fuchs (2010), a holistic, theoretical framework is fully developed. Following Marx, Fuchs divides society into base and superstructure. The base consists of "the interplay of labour, technology, and nature so that economic goods are produced that satisfy human needs" (Fuchs, 2010, p. 26), while the superstructure "is made up by the interconnection of the political and the cultural systems, so that immaterial goods emerge that allow the definition of collective decisions and societal value structures"

(Fuchs, 2010, p. 26). Following Wolfgang Hofkirchner, Fuchs uses a typology to classify social theories into four different kinds, namely reductionist, projectionist, dualist and dialectic approaches. Reductionism means that explanations are reduced to the base, in other words that ecology, economy or technology are seen as the driving force towards a sustainable information society (SIS). Projectionism means that the superstructure is seen as what counts, meaning that polity and/or culture is seen as the determinant force for a SIS. Dualism means that both base and superstructure are acknowledged, but they are separated from each other. The approach that Fuchs advocates is the dialectic approach, which is described as follows: "Multiple interrelated dimensions and goals of a SIS are identified, existing contradictions of these dimensions are analysed, and necessary changes are conceived as integral, interdependent, and systemic" (Fuchs, 2010, p. 30). Fuchs then develops the notion of a PCSIS, a participatory collaborative SIS, which also pays attention to collaboration and participation. The gist of the argument is that "sustainability should be conceived as being based on dialectics of ecological preservation, human-centred technology, economic equity, political freedom, and cultural wisdom. These dimensions are held together by the logic of co-operation, i.e. the notion that systems should be designed in ways that allow all involved actors to benefit, co-operation is the unifying and binding force of a PCSIS, it dialectically integrates the various dimensions" (Fuchs, 2010, p. 39). As has been indicated, while Fuchs is theoretically aware of the importance of the five dimensions of sustainability, his work has a tendency to conflate all the proposed dimensions into participation and collaboration, which he sees as the fundamental building blocks of society.

We are sympathetic towards Fuchs work, but believe that it can be complemented in a number of dimensions. First, although this paper is inspired by Fuchs studies on environmental sustainability, it is very clear from the review above that his main focus is not the environment. This is obvious from not only from the observed tendency to reduce all dimensions into the social, but also in the light of the works he refers to as well, for example the practical absence of sources on ecological Marxism (Martinez-Alier, 2002, 2007; Foster and Burkett, 2004; Moore, 2000, 2003; Luke, 1999). The theories this paper draws on pay more attention to the environment, rather than processes of participation and collaboration. Second, Fuchs theoretically proposes a dialectical view, consisting of five interrelated dimensions. If the assessment is correct that Fuchs theoretically proposes five interrelated dimensions, while he in practice narrows his scope, our ecological WST goes deeper in delving into the ways in which, for example technology, economy and society is related. In other words, bringing our dialectical approach to the table might be beneficial to advancing Marxian studies of ICT, particularly when it comes to ICT for sustainability purposes. Third, by using our framework, we might be able to advance Fuchs view on technology as not being just another dimension, but a very particular, almost magical, entity in contemporary society.

2.2 Ecological WST

WST was developed during 1970s by among others Immanuel Wallerstein as a way to expand the Marxian tradition of social studies – not the least Dependency Theory, developed by André Gunder Frank (1967). Rather than to discuss the class conflicts within a particular country, WST discusses inequalities on a global level (Chirot and Hall, 1982), based on Rosa Luxemburg's important remark that capitalism cannot be contained in itself, but must expand geographically in order to survive and prosper (Hornborg, 2001, p. 36). In other words, instead of addressing the exploitation of the working class by the capitalists, Wallerstein (2004) discusses exploitation by using three key concepts – the core, the semi-periphery and the periphery. The core is basically the developed, rich countries, while the periphery is the poor countries. The semi-periphery is in-between core and periphery.

The main argument in WST is that the wealth of core countries depends on exploitation of peripheral countries. Wallerstein argues that the success of developed countries today is a product of systematic unequal exchange of raw material, goods and labour with developing countries. The exploitation of the periphery, from the point of view of WST, started during the age of colonization and still exists in terms of trade between core and peripheral countries that constantly favour the core. The prosperity of core zones is thus not possible without the exploitation of peripheral zones, according to Wallerstein, just as capital accumulation is not possible without the exploitation of labour power of the working according to Marx. Wallerstein's analyses of world systems often revolve around economic and, as an extension, social effects of the unequal exchange between the core and the periphery.

Swedish human ecologist Alf Hornborg, while being inspired by traditional WST, has developed WST to take environmental effects into account (Hornborg, 1998b) and should be seen in the forefront of a tradition of studies connecting Marxism and ecology (Martinez-Alier, 2002, 2007; Foster and Burkett, 2004; Moore, 2000, 2003; Luke, 1999). In his analysis of world systems, the notion of exergy is vital (Hornborg, 2001). Hornborg claims that the concept of exergy, or the quality of energy – similar to negative entropy, or order – is important in order to understand the power relation between core and periphery. According to Hornborg, there is no consumption of energy, only of its quality and accessability, in other words exergy (Hornborg, 1998b). Similarly to Ilya Prigogne's concept of dissipative structures, Hornborg conceptualizes the world system as one which draws exergy or order into the core from the periphery and exports the entropy, or disorder, back to the periphery. The specific mechanism by means of which the world order is held in place is market prices.

Not only are the natural resources unequally distributed by this relation, but also the environmental effects that the usage of these resources leads to. This is termed "the global distribution of environmental degradation" by Hornborg (2001) and is based on the assumption that our world is a closed material system, a zero-sum game and not a cornucopian world where resources are unlimited. This means, according to Hornborg, that improvements in one part of the world system are always offset by deterioration in other parts of the world system. When natural resources are used by the core to increase the standard of living in the developed parts of the world, by, for example developing new technological equipment, the periphery suffers the environmental and social consequences. While the direct tone in Hornborg's work is appreciated, there does not necessarily have to be a zero-sum game. Rather than thinking only in terms if zero-sum games, one could imagine scenarios where there is indeed a net benefit, but that environmental effects are still distributed unequally – the core benefits more than the periphery.

Apart from describing exergy and the zero-sum game, Hornborg uses the notion of technology fetishism (Hornborg, 2001). Hornborg argues that in contemporary society, technology is seen as a solution to myriad problems. Rather than seeing technology as a saviour, Hornborg thinks of technology as being a fetish, in other words, something which is indeed an interworking part with the rest of society, but seen as imbued with almost magical powers. As opposed to this understanding, Hornborg sees technology as follows.

"This is the essence of human technology: the use of time and space to save time and/or space for some social category. Technology or capital thus amounts to a way of redistributing temporal and spatial resources in global society" (Hornborg, 1998a, p. 174).

Hornborg, however, claims that people often believe that technology in itself has the potential to solve problems (which means to see it as almost magical), while the functionality of technology is indeed dependent upon market prices of the input and the output. To understand that the inherent productivity of technology is dependent upon market prices, rather than posited as productive in and of itself, is to move away from a fetishistic, magical understanding of technology, according to Hornborg (2001). Related to this point, Hornborg explains how technology abstracted from its context (as in technology transfer for development purposes) fast becomes useless.

Hornborg's ecological WST responds to two sets of problems within WST. First, that WST seldom is concerned with exploring environmental effects. Second, that ecological WST provides a clear definition of exploitation consisting of the unequal exchange of exergy, where the cores are defined as the net importers of exergy, while the peripheries are seen as net exporters (Hornborg, 1998b). Apart from these benefits, WST has been critiqued for a number of issues, which Hornborg does not explicitly address. First, it has been argued that WST is too state-centric and fails to address interdependencies and complexities of the international world order (Gill, 1992, p. 271). Second, it has been argued that WST is far too structuralist and does not allow for the production of history based on the collective efforts of people with agency (Germain and Kenny, 1998). In response to this critique, our theoretical understanding of the tenets of ecological WST is somewhat nuanced.

While this paper subscribes to the theoretical notion that environmental effects are distributed unequally in the world system, it pays heed to the complexities of the world system, particularly after the end of the Cold War. This means that states can no longer be the central unit of analysis. Rather, the analysis should pay attention to the multifarious milieu of international organizations, business corporations, states, regional government and global and local non-governmental organizations all shaping the world system. While the concepts of "core", "semi-periphery" and "periphery" are retained in the analysis, we do not see these concepts as attributes of states. Rather, the paper is inspired by the concept of a "spiky world", an image that was produced to portray how populations, economic activity and patents are unevenly distributed in the world (Florida, 2005). It is held that there are spikes also when it comes to environmental degradation, which also indicates the misconception of basing a WST on states.

Also, in response to the critique of WST being structuralist, our theoretical framework is more responsive to other aspects of the world system, for example how cultural and popular discourses contend to become dominant, or in Gramsci's words "hegemonical" (Gill, 1992). This cultural move is a way to integrated base and superstructure, to produce a dialectical approach, discussed by Fuchs. Similarly to Gramsci, Hornborg strives for an interfusion of the social and the material, paying attention to both unequal exchange in terms of exergy and hegemonical discourses that not only make such exchanges possible, but sometimes veils the rising global anticipation of disaster (Hornborg, 2009). The "discourse analysis" is often used by Hornborg to highlight conflict rather than consensus. Another response to the critique of being structuralist, the response is a more historically grounded approach. Not only discourses, but also relations within the world system might change in unexpected ways.

Paying attention to the tendency of modern society to highlight the usefulness, or almost magical qualities, of technology, our perspective recommends one to take a critical perspective on technology. This is related not only to deconstructing discourses about technology, but also to assess the distributions of environmental impact within the world system.

2.3 WST and ICT

It seems as even though infotization is a major trend in world, world system theorists have been rather silent upon issues relating to ICT. There are however some important contributions where WST has been applied to issues related to ICT. These will be presented and discussed in this section.

Konieczny (2012) argues that early ICTs such as printing technologies, the telegraph and the television were invented, developed and deployed in the core, which means that the core "had decades if not centuries of near monopoly on their use" (Konieczny, 2012, p. 260). He argues that the case of the internet is no different as it relies on expensive technologies and skills that are hard to come by in the periphery. However, while there are WST inspired debates about the digital divide, there are also important positive effects identified by world systems theorists. While traditionally having been used mainly by western core countries, the number of Chinese users is increasing dramatically. In mid-2004, English speakers constituted 36 per cent of internet users, while Chinese users constituted 13 per cent. Five years later, the English accounted for 28 per cent of the internet population, while the Chinese accounted for 23 per cent. Konieczny thereby notes how the internet indeed harbours potential for a more just and equitable use of information technologies.

By focusing more on the actual equipment of ICT, Nelson-Richards *et al.* (2012) show how core countries invest heavily in ICT and that investments in ICT often lead to higher productivity and business performance, which is to be expected. This shows that they are aware of the productivity paradox of ICT, which would imply that the core deliberately distances itself from the periphery.

Lawrence (2012) discusses the intersection between energy use and WST. There is a strong positive correlation between energy use and a country's position in the world system. The semi-periphery, such as China, Lawrence argues, uses more energy and produces more emissions, while the periphery has experienced and increase in energy use and GHG emissions, but to a lower extent than the semi-periphery.

Smith *et al.* (2006) are portraying the negative environmental and social effects of the production of the latest high-tech gadgets. They focus on the US and on the emergence of the high-tech industry in what was going to become the Silicon Valley in the 1980s. Sonnenfeld argues that "[h]ierarchies of power, profitability, and control are embedded within the structure of global economics. Key firms such as Intel and Hewlett-Packard remain headquartered in Silicon Valley, even while their manufacturing operations are distributed around the world". (Smith *et al.*, 2006, p. 13). Even though high-technology equipment is mainly used and developed in the core and semi-periphery, the lion's share of the production and have been moved to periphery.

On the same topic, Frey (2003) shows how health and environmental hazards are transferred to the periphery of the world system. Many governments in peripheral countries are willing to accept hazardous production processes and recycling of dangerous wastes such as ocean-going vessels, e-waste and automobile batteries, in order to gain economic advantage (Frey, 2003; Buerk, 2006). The economic earnings of these tradeoffs only affects a small portion of the peripheral country, i.e. those in power, while the negative impacts affect the whole population.

In relation to our own theoretical understanding of ecological WST, the literature reviewed can be characterized following our three tenets of ecological WST as presented in the previous section. Some of the studies such as Nelson-Richards *et al.* (2012) and Lawrence (2012) fall into the trap of "state centeredness", while other studies such as Smith *et al.* (2006) and Frey (2003) are congruent with our approach, discussing environmental effects in different parts of the same state. Furthermore, the studies focus on the material dimension and do not discuss the discourses of ICT and sustainability. This might be a sign of WST still being seen as structural, neglecting the cultural and discursive aspects of phenomena, in other words, the superstructure. Lastly, the reviewed studies show that there are different environmental effects of ICT in different parts of the world system. These studies take a critical perspective on ICT, especially with regards to the unequal distribution of environmental effects. However, when it comes to the superstructure, the cultural and discursive side, they remain silent.

The following part consists of a discussion of the discourse of ICT and sustainability, followed by a tentative analysis of unequal exchange of environmental effects.

3. The base and superstructure of ICT and sustainability

3.1 Superstructure: from Green Computing to Sustainable ICT

Following Hornborg's interest in discourses, or the superstructure (Fuchs, 2010), this section focuses on the popular discourses of ICT and sustainability. Our analysis of discourses of sustainable ICT practices is inspired by Hornborg's analysis of the discourse the role of technology for sustainable development from the 1960s to the 1990s (Hornborg, 2001, pp. 16-22). It will be argued that the popular discourse of ICT and sustainability consists of three historical phases – Green Computing, Green IT and Sustainable ICT.

In 1992 the US Environmental Protection Agency launched the voluntary programme Energy Star, which is an energy-efficiency certification for electronic devices, mainly seen on old CRT monitors. Several other similar concepts emerged during the same time period, emphasizing energy-efficiency as well as sustainable production and recycling of ICT equipment and other electronic devices (i.e. EPEAT, TCO certification). The focus of this phase, which we call Green Computing, was on the environmental aspects of the ICT devices themselves; energy use, sustainable production and recycling.

Several years later another discourse emerged which also emphasized sustainable ICT practices – Green IT. Gartner Institutes released a whitepaper in 2007, which showed that around 2 per cent of the total energy consumption of Great Britain was due to the usage of ICT equipment. This was almost as much as the airline industry. The main difference between this discourse and the previous one was that within Green IT, ICT was not only seen as the villain of the environmental issues, but more importantly, as a part of the solution (Fors and Lennerfors, 2013). The practices of Green Computing was termed "greening of IT" while the part of the concept where ICT could be the solution was called "greening by IT". Practitioners argued that while greening of IT could address about 2 per cent of the potential of Green IT, greening by IT accounted for the remaining 98 per cent by providing "smart" solutions such as route planning, web meetings, virtualisation of servers and dematerialization (Fors and Lennerfors, 2013). To sum up, the discourse of green IT started as a renewed concern with the amount of energy consumed by ICT equipment. However, it got more and more focused on the practices of greening by IT rather than greening of IT. It is plausible that a focus on greening by IT would to further penetration of ICT into different societal sectors, increasing the "technomass", while a focus on greening of IT would lead to a decrease in the production and usage of ICT equipment.

During Green IT, a burgeoning development, something we call "the third wave" of sustainable ICT practices, started to gain a foothold. Sustainable ICT, where economic and societal aspects are added to the environmental concerns of Green IT and Green

Computing, became the new buzzword. Sustainable ICT focuses more on the "greening by" practices of green IT, while adding what ICT can contribute with economically and socially. According to Harmond and Demirkan (2011), this wave of sustainable computing will require organizations to consider "environmental (ecological and regulatory), social (ethical and philantropic) and economic strategies while delivering on core IT performance requirements to drive business productivity" (Harmon and Demirkan, 2011, p. 19). To summarize this wave of sustainable ICT practices one could argue that sustainability within the ICT sector can now be equated with any other ICT practice in business settings. While increasing economic, social and ecological aspects of the core where these practices are carried out, Sustainable ICT will inevitable contribute to social and ecological degradation in peripheral areas.

During this whole development, there are a few notable shifts taking place. First, there has been a shift from seeing ICT as an environmental threat to a potential solution. From Green Computing, where ICT equipment should be used carefully and more efficiently, the discourse has evolved into Sustainable ICT, where ICT has a big potential of solving economic, societal and environmental issues (in the core). In other words, the discourse on ICT and sustainability is turning increasingly optimistic. This is related to what Hornborg describes as consensus rather than conflict. While in the era of Green Computing, and Green IT, there were potential conflicts between ICT and sustainability, nowadays ICT and sustainability goes hand in hand.

Moreover, most probably related to the shifts in discourse, the dominant parties standing behind the discourses are changing. The discourse of Green Computing was developed by environmental agencies while the increasingly optimistic discourse within Green IT and Sustainable ICT is mostly produced by the industry. Sustainability is in the era of Sustainable ICT is generally described as a business strategy, used in order to gain market advantages. Within Sustainable ICT, there is no significant difference between Sustainable ICT practices and just any other ICT practice within a business corporation. A shift where corporations and business associations have likely reached a position of dominance, or hegemony, in producing discourses about ICT and sustainability, could be perceived. A third characteristic, which has remained constant during the phases is that the discourse is produced in the core areas of the world system.

3.2 Base: the value chain of ICT

In this section, a value chain perspective on ICT is adopted. Studies about ICT from materials extraction to manufacturing, use, refurbish and reuse and finally disposal are reviewed. Given the theoretical framework of this paper, examples of unequal distribution of environmental degradation will be identified. This part does not aim to be a systematic analysis and a proof of that ICT leads to the unequal distribution of environmental effects. Rather, it is a collection of examples of the ICT value chain aiming to give an idea of what a thorough application of ecological WST to ICT could lead to. Thus, the aim of the part is to indicate how the most positive benefits of ICT appear in core areas, while the more negative impact appears in the periphery.

3.2.1 Materials extraction. The production of ICT equipment depends on the supply of raw materials, often extracted in peripheral areas of the world. Mining activities are always linked to some environmental destruction to the local environment. Del Mar (1885) argues from a historical perspective that the mining for precious metals has caused severe long-lasting damage to the local environment, still present 2000 years after the original damage was caused. Processes like leaching uses highly toxic and/or cancerogenic chemicals such as fluorine, mercury and arsenic. Large quantities of water are used for filtering, which subsequently is deducted from the supply of available drinking water in the local area. Mining also generates large amounts of waste, which is often toxic and destroys the ecosystem. For example, extracting one tonne of copper generates 600 tonnes of waste, which needs to be disposed of (Gulbrandsen, 2012).

REEs are the elements needed to give electrical products certain properties, and very small amounts are needed in the electrical gadgets people use in their daily lives. REEs make it possible to produce energy efficient fluorescent light bulbs and add power-saving abilities in certain technological devices. But the energy saved in the core is offset with environmental costs in the peripheral zones (Pitron and Turquier, 2012). In the extraction and refinement stage, several environmental implications can be identified, such as contaminants from the open mining pit to the ground water of the local environment.

3.2.2 Manufacturing. The manufacturing of ICT equipment is also linked with many environmental implications. Williams (2004) argues that the lifecycle energy consumption of ICT equipment is dominated by the production (81 per cent) as opposed to the operation (19 per cent). James and Hopkinson agree with Williams and state that "when all impacts are considered, the materials and manufacturing stage probably has the greatest environmental impact" (James and Hopkinson, 2008 p. 28). Studies on notebooks show that the production phase, accounting for about 56 per cent of the total GHG emissions of the life cycle, has a significantly higher impact than the use phase. Moreover, the environmental impact of the production phase of a notebook is so high that it cannot be compensated in realistic time-periods by energy efficiency gains in the use phase. In the case of a 10 per cent increase in the energy efficiency of a new notebook as compared to the older one in the use phase, replacement of the older notebook can only be justified after 33-89 years, when all environmental aspects are considered (Prakash *et al.*, 2012).

Another study shows that the total amount of secondary fossil fuel and chemical input to the production of a two gram 32 MB DRAM chip is 1,600 and 72 grams, respectively. One of these small components also requires 32,000 litres of water to produce (Rattle, 2010). While the size of chips decreases, the used materials might actually increase. Although dematerialization is more than decreasing the size of the components, this throws doubt upon some of its potential.

3.2.3 Use. The use phase is where the environmental benefits of ICT can be reaped, according to recent reports (e.g. GeSI, 2012). The use phase allows for dematerialization – such as streaming music instead of listening to CDs and reading on-screen instead of on paper – and the development of smart ICT solutions. Although the potential for ICT in this phase seems huge, some have questioned the viability of these solutions. While some argue that ICT in the form of web meetings generates less need to travel and meet physically, others have argued that the number of physical meetings does not decrease (Rattle, 2010; Fuchs, 2008). The potential of streaming media from "the cloud" has also been presented as an environmental gain of ICT. However, it seems as if streaming actually may consume more energy than producing and shipping the media on a DVD or a CD, as the servers where these files are located need electricity and cooling. Furthermore, while it has been suggested that around 80 per cent of the energy consumption of PCs occur during the production phase (Williams, 2004), a 2007 EU study by The Swedish Institute of Production Engineering Research reached the opposite result (Jönbrink and Zackrisson, 2007). They suggest that 82 per cent of the lifetime global warming impacts of a European office desktop computer are related to use the use phase, compared to 18 per cent in production.

3.2.4 Refurbish and reuse. As environmental impact of refurbishing of ICT equipment is a rather under-studied area, we draw on empirical examples from our own research in this section. Some Swedish refurbishers have found a niche market in prolonging the life of computers by selling them second-hand to semi-peripheral countries before they actually become waste. They mainly sell proper second hand computers to countries in Eastern Europe, since in Sweden the demand for second hand ICT equipment is very limited. While this stage prolongs the lifetime of equipment, it has some environmental implications, because the infrastructure of most semi-peripheral areas cannot handle electronic waste properly. First of all, this means that precious materials from the equipment will not be recycled. Second, it could result in exportation of e-waste from the semi-periphery to the periphery.

3.2.5 Disposal. E-waste is a major issue when it comes to ICT and sustainability. According to EPA, only around 27 per cent of the electronic waste is recycled in the USA, and there are several reasons to this. First of all, electronic waste is hard to recycle, as it consists of many different materials. This also makes it expensive, causing a lot of waste to be exported to peripheral areas from the core. According to The Basil Action Network, western e-waste, primarily from the UK and USA, is illegally exported to different countries in Southeast Asia and Africa. In 2008, it was estimated that 275,000 tonnes of e-waste was being exported on a yearly basis (Kostigen, 2008). This waste is not properly treated; motherboards are melted over open fires, releasing mercury fumes and dioxins of flame-retardants in order to extract precious metals such as gold and silver. Cables containing copper is also treated in a similar way.

3.3 Analysis of base and superstructure

Connecting our theoretical framework to our descriptions of what goes on in the base, there are at least have some indications that environmental degradation in relation to ICT is unequally distributed, stated by Hornborg (1998b) as the "export of disorder". Materials extraction usually occurs in peripheral regions in peripheral countries, but also in peripheral areas of core countries. Manufacturing often takes place in semi-peripheral regions, for example in parts of China, which neither classifies as core nor periphery. The use phase is global but as Fuchs and Horak (2008) point out, better and faster ICT equipment is used in core regions. The potential of Sustainable ICT is thus highest in these regions, but such core regions can exist, for example in traditional non-core countries such as China. We do not neglect that the use of ICT solutions can lead to improved sustainability in peripheral regions (e.g. regarding agricultural management in developing countries). Still, the description indicates that the potential is greater in core areas.

When it comes to refurbishing, it can be seen how older ICT equipment trickles down from core to semi-periphery to periphery. This could be seen as an "export of disorder" or entropy, which takes place from core regions to peripheral regions. The same is true of the illegal export of e-waste, which is another example of export of disorder. Certainly, it has been noted how Swedish metal producing corporations convert e-waste into raw materials, such as copper. However, there are also indications that only first grade e-waste is used for this operation (motherboards), while other kinds of less valuable e-waste is sold abroad. In other words, also in the sorting of e-waste there is a separation of different kinds of e-waste that are recycled in different parts of the world. By this tentative analysis, it has been indicated that there seems to exist an unequal distribution of environmental effects in the world, where core areas enjoy less environmental harm than semi-peripheral or peripheral areas.

According to Hornborg's zero-sum game, some region profits, other regions suffer. It is probably almost impossible to assess whether there is a zero-sum game or not, especially from the reviewed studies. However, what can be seen is that the cornucopian scenario is probably not correct. The earlier studies show how not all regions benefit from environmental effects of ICT, rather that some regions suffer more than others. ICT is not cornucopia, but whether it is a zero-sum game or not is difficult to say.

Regarding Hornborg's third point, technology fetishism, it seems obvious that in the popular discourse of Sustainable ICT practices, the superstructure, the world is moving into a fetishist era where ICT is seen as an economic, social and environmental saviour. But drawing on the research related to the base of ICT, reality fails to live up to the promise of the discourse. The findings of a harmonious and cornucopian superstructure and a less cornucopian base, is similar to the findings of Hornborg. The promise of Sustainable ICT, where ICT is seen as a positive contributor to environmental, social and economic sustainability, in the superstructure could actually contribute to increasing the environmental degradation divide between core and peripheral areas while veiling the global anticipation that ICT might not always be beneficial for the environment (cf. Hornborg, 2009). The paper therefore has shown how the base and the superstructure partly tell different stories – in other words, it has used the "discourse analysis" to highlight conflict rather than consensus.

4. Concluding discussion

In this paper we have proposed a framework of ecological WST as a way to advance critical studies of ICT, beyond the most prevalent Marxian approach, namely Fuchs work. The paper has drawn mostly on Alf Hornborg's work to construct the framework, but we have also addressed some of the critiques of WST, responding to the new conditions in a changing world, more specifically to escape state centrism and structuralism, by paying heed to regions (or "spikes"), and cultural discourses.

By describing the superstructure of ICT and sustainability, namely the shifting discourses from Green Computing to Sustainable ICT, it has been shown how at a popular discursive level, ICT is increasingly seen as a saviour. However, studying the base, it is seen that cornucopia, or the limitless positive potential of ICT fail to live up to its promises.

There is a range of implications of our work. The paper has contributed to Marxian studies of ICT, by bringing in theories that are explicitly interested in environmental sustainability. By combining superstructure and base, it has also proposed an alternative dialectic approach to the one proposed by Fuchs. The paper has also shown how the discourses of ICT portray an image which is much more positive than the world that is far from cornucopian. In terms of practical implications of our work, it is maintained that ecological WST could be used when performing environmental assessments, for example by means of life-cycle analysis. In life-cycle analyses inspired by ecological WST, one would have to take into account the distribution of environmental effects in core, peripheral and semi-peripheral regions.

In the introduction, a discussion of our findings in relation to non-Marxian work on sustainable ICT practices was promised. This paper will end by engaging in a discussion with the few studies that have tried to provide a theoretical framework for understanding the role of ICT for sustainability, often described as having economic, social and ecological dimensions (Serageldin, 1995, p. 17). The first is the work of Lorenz Hilty and colleagues, while the second is the work of Norberto Patrignani and Diane Whitehouse.

Hilty *et al.* (2006) describe the positive and negative aspects of ICT and classify them into first-order effects (effects of the physical existence of ICT), second order effects (indirect environmental effects of ICT due to its power to change processes resulting in a modification of their environmental impacts) and third-order effects (environmental effects of the medium or long-term adaptation of behaviour of economic structures due to the stable availability of ICT and the services it provides). Through a simulation of environmental indicators such as different types of transport and different means of electricity consumption they demonstrate that there are relevant potential impacts on environmental sustainability in all three orders, but that "on an aggregated level, positive and negative impacts tend to cancel each other out" (Hilty *et al.*, 2006, p. 1628). Similarly to our approach, Hilty *et al.* suggest that positive and negative effects cancel each other out, in other words, it is a zero-sum game. However, in contrast to our approach, they do not split their findings into consequences for different zones in our world system.

In another paper, Hilty and Ruddy (2010) suggests that the way in which ICT can have positive impacts on sustainability is by dematerialization, but they present macroeconomic data showing that the economy is not dematerializing. They hold that incentives must be stronger in order to use ICT for dematerialization. Related to our ecological WST, it should be stated that Hilty and Ruddy (2010) are well aware of the world system aspects in their discussion about how people in rich countries consume much higher quantities of energy and materials. However, our framework pays much more attention to technology as situated in a world system, rather than technology as such. As Fuchs (2010) states, Hilty and Ruddy are reductionists (see Section 2.1), in that they reduce the question of sustainable ICT practices to the base (energy, materials, economic incentives). Hilty is not particularly optimistic with regards to technology *per se*, but rather sees hope in economic incentives. Based on Hornborg's work, it is argued that technology and economy is intrinsically related, which means that it is incorrect to separate technology and economy. Also, while Hilty believes in dematerialization, the ecological WST would urge one to look for potential downsides (zero-sum game effects) of dematerialization. For example, it was noted in this paper that smaller chips can lead to more resource use.

Patrignani and Whitehouse with their notion of Slow Tech, which is inspired by the concept of Slow Food, subscribe to the multi-dimensionality of sustainability arguing that "ICT must be positioned in terms of three important criteria: good, clean, and fair" (Patrignani and Whitehouse, 2014, p. 80). The concept of Slow Tech, should according to the authors, not be seen as slow technology, but rather a concept which enables people to reflect, stand back and consider. Good ICT, in other words human-centred ICT, help people enhance their health and well-being in order to find an appropriate balance between work, social obligations and personal time. Clean ICT focuses on avoiding harm to the environment, animal welfare and human health. Clean ICT tries to slow down the ICT life cycle and to extend the lives of ICT equipment. Fair ICT can be defined as being "respectful of the human rights, self-esteem, and health and safety, of workers in ICT manufacturing as well as of ICT users" (Patrignani and Whitehouse, 2014, p. 85). They conclude that Slow Tech is a means of rethinking the pace of development of ICT and they give proposals about how Slow Tech could be adapted.

Patrignani and Whitehouse's concept of good, clean and fair ICT is indeed positive and inspiring. However, they run the risk, similarly to the discourse of Sustainable ICT, to be far too abstracted from the current state of affairs. The discourse can be appropriated and turn into a veil that hides underlying conflicts and inequalities in the distribution of sustainability. Furthermore, there is a risk that although there are empirical examples of Slow Tech (Patrignani and Whitehouse, 2014), Slow Tech cannot be the dominant paradigm, given the world system dynamics of ICT. Sticking to the food metaphors of Patrignani and Whitehouse, one could argue that no matter how much we treat cows with respect, feed them ecological food, pay the farmers a fair compensation for their work and do not transport them across the country to be butchered, raising cows is still highly energy intensive and demands large amount of pasture. However, while some pessimistic world system theorists assume that the inherent power differences in the world system will halt any progress towards a sustainable society, we maintain that it is important to have a vision, like Patrignani and Whitehouse (or Fuchs for that matter), but it is equally important to clearly have a view of the dynamics within the world system, which need to be taken into account in order to promote sustainability on a world level.

References

Buerk, R. (2006), *Breaking Ships: How Supertankers and Cargo Ships are Dismantled on the Shores of Bangladesh*, Chamberlain Brothers, New York, NY.

Chirot, D. and Hall, T.D. (1982), "World-system theory", *Annual Review of Sociology*, Vol. 8 No. 8, pp. 81-106.

Cisco (2015), "Cisco visual networking index: global mobile data traffic forecast update, 2014-2019", avaliable at: www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf (accessed 8 October 2015).

Del Mar, A. (1885), "A history of the precious metals, from the earliest times to the present", avaliable at: http://archive.org/stream/historyofpreciou00delmuoft/historyofpreciou00delmuoft_djvu.txt (accessed 8 October 2015).

ECC (2011), "International report on mobile broadband landscape", avaliable at: www.cept.org/files/4549/ECC%20PT1%20internal%20report%20on%20MBB%20-%20ECC%20PT1(11)162%20Annex%2023.docx (accessed 8 October 2015).

Fairweather, B. (2011), "Even greener IT. Bringing green theory and 'green IT' together, or why concern about greenhouse gasses is only a starting point", *Journal of Information, Communication & Ethics in Society*, Vol. 9 No. 2, pp. 68-82.

Fehske, A., Fettweis, G., Malmodin, J. and Biczok, G. (2011), "The global footprint of mobile communications: the ecological and economic perspective", *IEEE Communications Magazine*, Vol. 49 No. 8, pp. 55-62.

Florida, R. (2005), "The world is spiky", *The Atlantic*, available at: www.theatlantic.com/past/docs/images/issues/200510/world-is-spiky.pdf (accessed 8 October 2015).

Fors, P. and Lennerfors, T.T. (2013), "Translating green IT: the case of the Swedish green IT audit", in Hilty, L.M., Aebischer, B., Andersson, G. and Lohmann, W. (Eds), *Ict4s 2013: Proceedings of the First International Conference on Information and Communication Technologies for Sustainability*, ETH E-Collection, Zürich, 14-16 February, pp. 208-216.

Foster, J.B. and Burkett, P. (2004), "Ecological economics and classical marxism", *Organization & Environment*, Vol. 17 No. 1, pp. 32-60.

Frank, A.G. (1967), *Capitalism and Underdevelopment in Latin America*, Monthly Review Press, New York, NY.

Frey, R.S. (2003), "The transfer of core-based hazardous production processes to the export processing zones of the periphery: the maquiladora centers of northern Mexico", *Journal of World-Systems Research*, Vol. 9 No. 2, pp. 317-354.

Fuchs, C. (2006), "The nature-society-system and the global sustainable information society (GSIS)", in Trappl, R. (Ed.), *Cybernetics and Systems*, Vol. 2, Austrian Society for Cybernetic Studies, Vienna, pp. 389-394.

Fuchs, C. (2008), "The implications of new information and communication technologies for sustainability", *Environment, Development and Sustainability*, Vol. 10 No. 3, pp. 291-309.

Fuchs, C. (2010), "Theoretical foundations of defining the participatory, co-operative, sustainable information society", *Information, Communication & Society*, Vol. 13 No. 1, pp. 23-47.

Fuchs, C. and Horak, E. (2008), "Africa and the digital divide", *Telematics and Informatics*, Vol. 25 No. 2, pp. 99-116.

Fuchs, C. and Mosco, V. (2012), "Introduction: marx is back – the importance of marxist theory and research for critical communication studies today", *tripleC: Communication, Capitalism & Critique*, Vol. 10 No. 2, pp. 127-140.

Germain, R.D. and Kenny, M. (1998), "Engaging gramsci: international relations theory and the new gramscians", *Review of International Studies*, Vol. 24 No. 1, pp. 3-21.

GeSI (2012), "GeSI SMARTer 2020: the role of ICT in driving a sustainable future", available at: 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

Gill, S. (1992), "Economic globalization and the internationalization of authority: limits and contradictions", *Geoforum*, Vol. 23 No. 3, pp. 269-283.

Gulbrandsen, C. (2012), *Stealing Africa – Why Poverty?*.

Harmon, R.R. and Demirkan, H. (2011), "The next wave of sustainable IT", *IEEE Computer Society*, January/February, Vol. 13 No. 1, pp. 19-25.

Hilty, L.M. and Ruddy, T.F. (2010), "Sustainable development and ICT interpreted in a natural science context", *Information, Communication & Society*, Vol. 13 No. 1, pp. 7-22.

Hilty, L.M., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M. and Wäger, P.A. (2006), "The relevance of information and communication technologies for environmental sustainability", *Environmental Modelling & Software*, Vol. 21, pp. 1618-1629.

Hopkins, T.K., Wallerstein, I. and Bach, R.L. (1982), *World-Systems Analysis: Theory and Methodology*, Sage Publications, Beverley Hills, CA.

Hornborg, A. (1998a), "Ecosystems and world systems: accumulation as an ecological process", *Journal of World-Systems Research*, Vol. 4 No. 2, pp. 169-177.

Hornborg, A. (1998b), "Towards an ecological theory of unequal exchange: articulating world system theory and ecological economics", *Ecological Economics*, Vol. 25, pp. 127-136.

Hornborg, A. (2001), *The Power of The Machine: Global Inequalities of Economy, Technology, and The Environment*, Rowman Altamira, Lanham, MD.

Hornborg, A. (2009), "Zero-sum world, challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system", *International Journal of Comparative Sociology*, Vol. 50 Nos 3-4, pp. 237-262.

Hornborg, A. (2011), *Global Ecology and Unequal Exchange: Fetishism in a Zero-Sum World*, Routledge, New York, NY.

Hornborg, A. and Jorgensen, A.K. (2010), *International Trade and Environmental Justice: Toward a Global Political Ecology*, Nova Science Publishers, New York, NY.

James, J. (2003), *Bridging the Global Digital Divide*, Edward Elgar Publishing.

James, P. and Hopkinson, L. (2008), *Energy and Environmental Impacts of Personal Computing*.

Jönbrink, A.K. and Zackrisson, M. (2007), Preparatory studies for Eco-design Requirements of EuPs: Lot 3 Personal Computers (desktops and laptops) and Computer Monitors, Final Report.

Konieczny, P. (2012), "The internet and the world-system(s)", in Babones, S. and Chase-Dunn, C. (Eds), *Routledge International Handbook of World-Systems Analysis*, Routledge, New York, NY, pp. 260-261.

Kostigen, T. (2008), "The underbelly of globalization: our toxic wastes exported to developing countries", available at: http://ban.org/library/Features/080925_the_underbelly_of_globalization.html (accessed 25 August 2014).

Lawrence, K.S. (2012), "Energy use and world-system dynamics", in Babones, S. and Chase-Dunn, C. (Eds), *Routledge International Handbook of World-Systems Analysis*, Routledge, New York, NY, pp. 409-410.

Lennerfors, T.T. (2014), "Sustainable and fast ICT: lessons from dromology", *Journal of Information, Communication and Ethics in Society*, Vol. 12 No. 4, pp. 284-297.

Luke, T.W. (1999), *Capitalism, Democracy and Ecology, Departing from Marx*, University of Illinois Press, Chicago, IL.

Malmodin, J., Moberg, A.Z., Lunden, D., Finnveden, G. and Lövehagen, N. (2010), "Greenhouse gas emissions and operational electricity use in the ICT and entertainment & media sectors", *Journal of Industrial Ecology*, Vol. 14 No. 5, pp. 770-790.

Martinez-Alier, J. (2002), *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*, Edward Elgar, Cheltenham.

Martinez-Alier, J. (2007), "Marxism, social metabolism, and international trade", in Hornborg, A., McNeill, J.R. and Martinez-Alier, J. (Eds), *Rethinking Environmental History: World-system History and Global Environmental Change*, AltaMira Press, Walnut Creek, CA, pp. 221-237.

Mingay, S. (2007), *Green IT: The New Industry Shock Wave*, Gartner, Stanford, CT, available at:http://download.microsoft.com/download/E/F/9/EF9672A8-592C-4FA2-A3BF-528E93DF44EA/VirtualizationPublicSafety_GreenITWhitepaper.pdf (accessed 8 October 2015).

Moore, J.W. (2000), "Environmental crises and the metabolic rift in world-historical perspective", *Organization & Environment*, Vol. 13 No. 2, pp. 123-157.

Moore, J.W. (2003), "Capitalism as world-ecology: Braudel and Marx on environmental history", *Organization & Environment*, Vol. 16 No. 4, pp. 431-458.

Nelson-Richards with the assistance of Kandu E. Agbimson (2012), "The pervasiveness of ICT in our present modern world-system", in Babones, S. and Chase-Dunn, C. (Eds), *Routledge International Handbook of World-Systems Analysis*, Routledge, New York, NY, pp. 288-289.

Patrignani, N. and Whitehouse, D. (2014), "Slow Tech: a quest for good, clean and fair ICT", *Journal of Information, Communication and Ethics in Society*, Vol. 12 No. 2, pp. 78-92.

Pitron, G. and Turquier, S. (2012), *La sale guerre des terres rares*.

Prakash, S., Liu, R., Schischke, K. and Stobbe, L. (2012), "Timely replacement of a notebook under consideration of environmental aspects", available at: www.oeko.de/en/publications/p-details/timely-replacement-of-a-notebook-under-consideration-of-environmental-aspects/; www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4317.pdf (accessed 8 October 2015).

Rattle, R. (2010), *Computing Our Way to Paradise?: The Role of Internet and Communication Technologies in Sustainable Consumption and Globalization*, Rowman & Littlefield, Lanham, MD.

Serageldin, I. (1995), "The human face of the urban environment", *Proceedings of the Second Annual World Bank Conference on Environmentally Sustainable Development: The Human Face of the Urban Environment*, *Washington, DC*, *19-21 September, 1994*, pp. 16-20.

Smith, T., Sonnenfeld, D.A. and Pellow, D.N. (Eds) (2006), *Challenging the Chip: Labor Rights and Environmental Justice in the Global Electronics Industry*, Temple University Press, Philadelphia, PA.

Verdegem, P. and Fuchs, C. (2013), "Towards a participatory, co-operative and sustainable information society? A critical analysis of Swedish ICT policy discourses", *Nordicom Review*, Vol. 34 No. 2, pp. 3-18.

Wallerstein, I. (2004), *World-Systems Analysis: An Introduction*, Duke University Press, Durham, NC.

Williams, E. (2004), "Energy intensity of computer manufacturing: hybrid assessment combining process and economic input-output methods", *Environmental Science and Technology*, Vol. 38 No. 22, pp. 6166-6174.

Further reading

James, J. (2001), "Low-cost computing and related ways of overcoming the global digital divide", *Journal of Information Science*, Vol. 27 No. 6, pp. 385-392.

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