

Data Centres in 2030: comparative case studies that illustrate the potential of Design for the Circular Economy as an enabler of Sustainability

Deborah Andrews

Associate Professor of Design

London South Bank University

103 Borough Road, London, SE1 0AA

Beth Whitehead

Associate Sustainability Engineer

Operational Intelligence Ltd

Unit 2B03, South Bank Technopark, 90 London Road, SE1 6LN

Introduction

During the 1980s the British engineer and computer scientist Sir Tim Berners-Lee developed a digital information and communication language and network, which subsequently evolved to become the World Wide Web in 1989. Since then the user group has expanded from 'geeks', researchers and academics and over 4.2 billion people and 55% of the global population are now 'connected'.

While 'devices' (desk and laptop computers and mobile phones) serve as human-digital data interfaces, the hidden but critical enabler of connectivity is data centres (DCs). These facilities may be cupboard-sized or, like the largest in the world, equivalent in area to 93 football pitches, but all house digital data processing, networking and storage (ICT) equipment. Such is the popularity of the internet that since its launch the number of DCs around the world has grown to 8.6 million (Infiniti Research, 2015) with a total floor space of 180 million m²; 10 million m² of which is in Europe with 70% concentrated in North West Europe (NWE). The main concern of the DC industry is 100% uninterrupted operation for customers and consequently, focus within the sector has been technical and product development, manufacture and operation with limited consideration of treatment at end-of-life. This paper considers two potential scenarios and their impacts for the data centre industry (DCI) in 2030; the scenarios are speculative and are based on past and present trends in and experience working with this unique sector.

Current and future growth in Connectivity and the Data Centre Industry

Such is the popularity and success of the internet that in Europe and the USA 85% and 95% of the population are connected respectively and more and more businesses, education and other service providers are becoming increasingly reliant on connectivity; in Africa and Asia even though the percentage of connected individuals is lower (36% and 49% respectively) population groups are much larger and consequently many more people are connected due to cheaper mobile devices (Miniwatts Marketing Group, 2018). Patterns of internet use vary according to user age, location and affordability: in developed countries such as the UK typically adults spend 4.75 hours per day online (IPA, 2018). In addition, data consumption has increased exponentially and concurrently with the number of work and leisure services on offer: for example, in 2016 the demand for data centre storage capacity increased by 1 Petabyte every day (Brewer et al, 2016). Growth will continue in order to process the increasing volume of data that will be generated by expansion of services via the Internet of Things (IoT), and commerce, healthcare, education, leisure services alongside population and economic growth in countries such as China and India.

It is apparent that there are differences in connectivity according to geographical location but there are even more extreme examples: in Iceland 98% of people are connected while in Somalia and Eritrea

connectivity is limited to 2% and 1% respectively. There is also a disparity among demographic groups and women, the rural poor and residents of remote islands 'are substantially excluded from education, business, and other opportunities that the internet can provide'. Sadly, since 2007 growth in many developing countries has slowed due to a number of factors including: limited and/or no 3G, 4G and wi-fi infrastructure, and the cost of network access, smart phones and computers (A4AI, 2018). As a result, the connectivity gap between different social and national groups is growing.

Reliance on and demand for data centres will increase as more people, smart products and services are connected. In NWE alone capacity will increase 15%+ per year (300%) by 2025 and a global increase of 500% is predicted by 2030. DC operational energy consumption will rise concurrently to facilitate this growth and even though DCs are becoming more energy efficient it is predicted that by 2025, 20% of global energy will be consumed by the sector (Andrae, 2017).

Environmental and social impacts

At present the largest environmental impact from DCs derives from operational energy; this is being addressed by improved operational efficiency and the use of renewables. However, in view of the above growth the embodied impact of DCs must not be ignored. During overall DC building life (60 years) 15% of embodied environmental impact derives from the building and facilities while 85% derives from IT equipment (Whitehead et al, 2015). Impact is high because equipment is regularly refreshed (servers every 1-5 years, batteries every 10 years and M&E equipment every 20 years). Although specific sectoral data has not been published, the DCI is a significant contributor to the global total of 11.8 Mt/year of Waste Electrical & Electronic Equipment (WEEE), which is one of the fastest growing waste streams across Europe and the world.

DC equipment is typically composed of 'common' metals (steel, copper, aluminium, brass and zinc), polymers (ABS, HDPE, PUR, PVC, GPPS, PBT, EVA) and 10 critical raw materials (CRM) - Sb, Be, Cr, Co, Li, Mg, Pd, Si, Dy, Nd, Pr, Tb. They are vital for economic growth but risk to supply is high and is affected by: their abundance/scarcity in the earth's crust; their geological and geographical location (which influences technical ease of extraction and political circumstances); current recycling rates; and potential substitution by more readily available materials. DC equipment is comprised of 99%+ 'common' metals and polymers and 0.2% CRMs; however, their importance cannot be underestimated because electronics cannot work without them. Gold, tin, tantalum and tungsten are similarly essential to electronic products; they are identified as Conflict Minerals because they are produced in central Africa and specifically the Democratic Republic of Congo where their (unethical) mining and sale funds armed conflict and political instability. The extraction processes of many of these and other materials also involves hazardous substances (e.g. arsenic, mercury, sulphides) and because a lot of their mining is unregulated and/or illegal the associated negative environmental and social impacts are high.

Post-use infrastructure

Both the speed and volume of current and predicted growth in digital communication technologies and their impact on all aspects of personal and public life among all populations is unprecedented. Current developments in computing such as faster processing speed and increasingly complex operating systems mean that, although server life is typically 1-5 years, it can be as short as 9 months (e.g. in Google and Facebook's Scandinavian 100,000 m² hyper centres). However, these developments in performance and manufacture have not been matched by development of a supporting infrastructure to deal with redundant DC equipment and/or waste.

In Europe there are currently about 20 million servers (data centre products); weight varies according to product type but assuming that the average weight of enterprise servers is 27kg this accounts for 0.56 million tonnes of materials (Peiró & Ardente, 2015). At present, however, WEEE recycling in Europe is limited to 32% and much of the rest is exported and reprocessed overseas and/or sent to landfill and consequently, hundreds of thousands of tonnes of valuable resources are wasted and/or made inaccessible by export every year from this sector.

Typically, 'common' metals are recycled because their properties are stable, quality is consistent, there is a well-established and economically viable infrastructure, and a market for these recycled metals. Disassembly and separation of products and components depends on the type of product and fixing - the disassembly of those with standard screws is relatively straightforward. However, many products are not designed for separation and those that are glued or riveted can at best be difficult and at worst impossible to separate without damaging one or all parts. Recycling polymers presents additional technical and economic challenges; for example, two-shot mouldings (where different product parts are

fused together as part of the simultaneous moulding process) are often comprised of different polymers which prohibits separation and therefore recycling. The market for and application of recycled polymers is also limited because their properties change when recycled and they are not necessarily suited to closed loop recycling (i.e. to make the same product again); the problems of recycling are compounded because it can be more economical for manufacturers to buy virgin as opposed to recycled polymers.

Electronics recycling is particularly challenging due to (sub)component composition from mixed materials that are not designed for separation. Many are also relatively small and their individual value is relatively low as a result of which, like polymers, it can be more economical to buy virgin rather than recycled materials and components. Electronics recycling in the data centre industry is magnified by particular challenges associated with data security, which means that even though data can be destroyed by 'wiping' memory, sometimes the process fails and the equipment must be shredded or owners want their equipment to be shredded anyway; related recycling and reclamation processes for higher value materials are being developed but at present they are predominantly small scale and/or experimental and a significant percentage of the shreds is not yet recycled.

It is apparent that the data centre industry provides an essential service to billions of people and that the global economy and more diverse sectors are becoming increasingly reliant on connectivity. It also appears that the DCI will continue to expand to meet growing market demand and volume of data traffic. However, the current sectoral economic model is linear, which raises questions about the long-term impact on resources, supply chain and the affordability of connectivity. In view of these factors, and based on current literature and trends, we now consider: two possible scenarios in 2030 for the data centre industry, the role of design as a contributor to and the wider implications of each scenario.

The Data Centre Industry in 2030

Since 2018 the data centre industry has grown five-fold to cater for the massive increase in data traffic and centres have proliferated in Europe, USA, cooler parts of Asia and the southern hemisphere. Although connectivity in some socio-economic groups and nations remains low, the number of connected individuals in countries that have experienced economic and population growth since then (particularly China and India), has also led to construction of data centres in cooler parts of these countries. The majority of data centres are still located in northern Europe and the USA because of proximity to 'Silicon Valley' and financial centres and because the lower temperatures and climate keep cooling costs to a minimum. Between 2010 and 2030 many large internet-orientated companies (such as Google, Facebook and Amazon) invested in land near to or in the Arctic Circle for this reason and because the area is politically stable; they have constructed and operate uber-hyper-centres that cover many millions of square metres but employ relatively few people because most operations are automated. Product refresh and therefore life is now around six months as developments in data processing and storage technology are ever more rapid. In addition to the uber-hyper-centres there are still a considerable number of smaller data centre owners and operators, many of which offer bespoke services to specialist sectors such as finance and healthcare; in these centres product refresh and life is longer at 1-2 years but still shorter than at the beginning of 2018. Consequently, the volume of waste and associated environmental impact is rising.

Future Scenario One: No Change

In 2030 the data centre industry as a whole remains linear and recycling and/or product reuse is still very limited as is information about the destination of equipment at end-of-life. The number and size of available landfill sites in Europe is increasingly restricted and consequently large volumes of waste are shipped overseas. Destination depends on materials' type because China has refused to import many types of polymer from Europe since mid-2018, although the Chinese and other Asian governments encourage the import of data centre equipment because it includes 'common' metals (that are easy to recycle) and electronics, (which are rich sources of CRMs, gold and other Conflict Minerals). A number of rich and powerful companies have bought mineral reserves and mines in countries other than their own (particularly in Africa) and, in conjunction with the growing stockpiles of redundant electronic products they are gradually gaining control over material supply chains for the data centre industry. Rising populations, GDP and disposable income has fuelled demand for and supply of electrical and electronics products in general, which, combined with the fact that many products cannot be easily disassembled, repaired or recycled, means that demand on resources has escalated. This in conjunction with ring-fencing and stockpiling of materials is beginning to have an impact on cost of resources, particularly CRM and Conflict Minerals which are essential to the data centre industry.

While Asian countries accept higher value electronic waste, poorer countries are becoming dumping grounds for waste and materials that are difficult to separate and then recycle other than by hand. Many companies remain ignorant of illegal and hazardous recycling and reclamation processes or claim that they cannot afford to recycle other than by using these low-cost services and consequently the health and life expectancy of many workers is adversely affected.

The rising cost of materials and thus data centre equipment is being passed on to end-users, and although the impact of these increases for many customers in the developed and developing world is negligible, they have an adverse effect on many less affluent end-users; the gap between the connected and unconnected has become even greater as access to education, healthcare and other vital services is ever more internet-based. This compounds many of the problems that arose between 2000 and 2020, for example: in the developed world, 'poorer' people are disadvantaged as personal smart devices and network access become less affordable which affects social mobility, resulting in increased poor health and social unrest. In the developing world, political instability, corruption (e.g. the sale of mining rights) and conflict thrives in parallel with growing demand for particular virgin materials, while the number of dispossessed, political and economic migrants grows.

Future Scenario Two – Change towards the Circular Economy

Since 2018 the data centre industry has grown five-fold but in 2030 the industry is benefitting from the gradual growth of a Circular Economy which was facilitated by several key changes. First, a sector-specific infrastructure for recycling and reclamation of materials (with emphasis on CRMs and Conflict Minerals) was developed (initially) for the European industry. This closed-loop infrastructure reduced export and the environmental impact of ocean transport (which was higher than that of road transport). Although it initially localised pollution from road vehicles, this is now changing with the use of more ultra-low and zero-emission vehicles in Europe. Investment in recycling processes and infrastructure positively accelerated their development, which is now proving economically beneficial as throughput is increasing and plants are expanding. Although a rise in demand for materials may increase landfill mining, increased recycling is currently limiting this activity which is beneficial because recycling newer 'clean' waste is more economical and makes identification and tracking of components and materials simpler as many are now clearly labelled. These factors have all enhanced quality monitoring and control of recyclates, as a result of which the market is growing and in many instances recyclates are becoming cheaper than virgin materials. In addition to recycling at end-of-life, Circular Economy waste reduction strategies include product life extension through reuse and remanufacture. Initially this proved challenging because equipment owners were very concerned about data security and many expected all redundant products to be shredded. However, a number of demonstration and training events and publicity campaigns have gradually enhanced trust in other data destruction processes, which have indirectly facilitated product life extension through reuse, component upgrades and remanufacture. In addition, data-wiping technology has improved and is more successful.

Initially the expansion of Euro-centric reuse and recycling facilities reduced waste flow to Africa, which had a negative impact on local employment and income generation; however, the European industry has expanded to the point where it can now form legitimate partnerships and set up sites there, which is proving advantageous because of the readily available workforce and its being closer to Europe than Asia. The partnerships will benefit from a combination of local (low tech) and imported (high tech) know-how and will create ethical, properly-paid jobs that enable locals to work in safe, non-hazardous environmentally-friendly conditions. Increased income will increase connectivity (and thus access to education and health services) as smart devices and networks become affordable. Increasing availability of quality controlled recycled materials is also reducing demand for virgin Conflict Minerals. These factors have all contributed to economic stability in the market for data centre equipment and services, which has the potential to reduce inequality between differing socio-economic groups.

The Role and Importance of Design in Future Scenarios 1 and 2

The data centre industry is unique in that its speed of growth and the impact of the service it provides are unprecedented. To date the sector has focused on technical development, meeting demand and uninterrupted supply, which will create problems as the volume of sectoral waste and demand for resources increases. These problems can be mitigated through development of a Circular Economy within the sector but this will be absolutely dependent on design, and therefore its importance cannot be under-estimated. The following design strategy reflects and enables a reversal of the current waste hierarchy: i.e. it enhances dematerialisation and reduces the volume of materials for disposal.

Reduce: dematerialisation/use less material per product – for example most data centre equipment sits in racks and therefore individual casings can be either reduced in size and mass and/or completely eliminated.

Reuse: ensure that data can be completely destroyed without shredding; there are opportunities to design new economical products to do this.

Remanufacture: develop and apply Design for Disassembly methods to facilitate component upgrade and refurbishment in order to extend product life several times.

Recycle: Design for Disassembly to enable easy separation of parts e.g. by eliminating adhesives and use of standard mechanical and/or smart fixings; find alternatives to composite materials and limit material mixing, e.g. two-shot polymer mouldings.

Energy from Waste: Design for Disassembly poses a significant challenge for electronic components but there is potential to work with specialists from other disciplines to develop tools and processes that facilitate separation of reusable and recyclable components; this and the above processes will reduce waste but any residual materials that cannot be reused or recycled must be incinerated with energy recovery in dedicated plants.

Disposal: reduce use of hazardous substances so that the environmental impact of any materials that end up in landfill is minimal.

Finally, designers need to identify new meaningful applications for recycled polymers and/or substitute with other materials.

Conclusion

The data centre industry is critical to 21st century life and its importance will increase concurrently with growth in and reliance on digital communication services. Two plausible scenarios for the industry in 2030 have been described; the first is based on current practice and does not involve change. It is evident that this scenario could create diverse, wide-ranging negative social, economic and environmental impacts in the immediate and long term.

The second scenario includes a sector specific Circular Economy, the impacts of which are also diverse and wide ranging, but in this case, they will be socially, economically and environmentally positive in the short and long term. This scenario can only be realised through significant changes in the design of data centre equipment. Such is the power of Design in this context that it can be seen as a direct and indirect enabler of sustainability. A significant question is whether these changes will be led by designers and innovators or driven by policy.

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