THE SCREENING LIFE CYCLE ASSESSMENT OF A DATA CENTRE

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Abstract

Data centres are low occupancy, high energy consuming facilities, and have the fastest growing carbon footprint in the ICT sector. Their impact on the environment is therefore of increasing concern. Current literature from the data centre industry shows a strong focus on operational energy which has led to the creation of numerous metrics largely concerned with energy use during the operational phase. Data centres, however, consume energy even before they are in use and continue to do so after they cease operation; producing impact from more than simply their energy consumption. Building Environmental Assessment Methods, such as BREEAM and LEED, are used to assess overall building sustainability. They have been adapted to include credits for the life cycle assessment of construction materials, but do not consider systems and components within the building such as the servers that are replaced every 3-5 years or the UPS batteries replaced every 10 years. For these reasons, a complete picture of the environmental impact of a data centre is difficult to construct.

This paper presents the application of Life Cycle Assessment (LCA) to data centre sustainability. Using LCA software, SimaPro, the method and results of a Screening LCA are described for an existing 13 MW data centre. The analysis shows that whilst the operational phase contributes 91.8% to the overall environmental impact; impacts from the biggest contributor – the IT equipment - on the ozone layer, ecotoxicity and minerals are all greater than 80% in the embodied phase, emphasising the need to consider multiple impacts beyond energy use in the full life cycle of data centres.

Keywords: Data centres, Screening Life Cycle Assessment, Environmental Impact, Resources, IT.

1. INTRODUCTION

1.1. Data Centres

Data centres house 'electronic equipment (such as servers) used for data processing, storage and communications networking' [1]. They typically have large footprints in order to house IT equipment and the additional building services required to power and cool them.

In 2011 data centres were found to account for 1.3% of total worldwide electricity use [2], and the UK was estimated to have 7.59 million m^2 of dedicated data centre space – equivalent to 14 Pentagons - and a peak power consumption of 6.44 GW [3]. Furthermore, in 2007 ICT was believed to account for 2% of global anthropogenic CO_2 [4,5] – roughly equal to that of the aviation industry – and a quarter of which is due to data centres [6].

1.2. Methods of Assessment

As a result of rising energy consumption by data centres, environmental impact has become increasingly important. Currently data centre metrics and Building Environmental Assessment Methods (BEAMs), such as BREEAM in the UK, have been adopted to benchmark their impact. The metrics use operational efficiency as a proxy for sustainability, and therefore miss any embodied impacts or impacts from anything other than energy consumption. Furthermore BEAMs award credits for reduced life cycle impacts of construction materials, but do not include the IT equipment which is replaced at least every 3 years. Because of this it is difficult to understand the true life cycle impact of data centres.

This research is therefore concerned with the full life cycle impact of data centres.

2. METHODOLOGY

The aim of the research was to quantify the environmental impact of an existing data centre and to understand the 'hotspots' in line with ISO 14040:2006 [7]. It was also necessary for the method to be manageable within the day-to-day running of a design project by using readily available LCI data held in software libraries. A Screening LCA was therefore developed using LCA software SimaPro 7.3.2 PhD which contains LCI libraries such as Ecoinvent. Where gaps in the data existed, Economic Input Output (EIO) data was used in a Hybrid LCA approach. EIO looks at the total emissions of industrial sectors within the economy and apportions part of this load to individual components based on their contribution to the total added value (value of the sector minus the value of purchases) of that sector. Such a method does not allow for comparison of components in the same sector, but does allow for comparison of systems from different sectors.

During data collection drawings and the Operations and Maintenance (O&M) Manual were used to build a Bill of Materials/Components/Systems (depending on the availability of data) for an existing data centre in Northern Europe. Where costs were required for EIO they were taken from the Spon's M&E Services Price Book 2011 [8]. The facility comprises a steel portal frame structure with composite floors totalling 42,500 m2 and accommodating 12 MW of IT; and cooling is provided by air-side free coolers, with a redundant chilled water system.

Date centre function would most accurately be considered on a 'per-compute' basis; however, this was too complex. Instead a 'per-kW of IT per-year' functional unit was used.

The system boundaries included all material and energy inputs and transport from the extraction of raw materials to the end-of-life. No specific data, however, was available for transport distances and a nominal assumption of 50 miles in a 28t truck was included to understand the potential. Though the impacts of construction and maintenance were omitted, replacement of equipment was accounted for on the following timescales: IT every 3 years, batteries every 10 years and facilities every 20 years. The building was assumed to have a life time of 60 years.

For construction materials, percentages of waste to recycling and landfill were taken from the 2010 WRAP report on construction waste [9] and it was assumed that all services were reclaimed and reused, though no benefits from avoided products were added to the system.

For the inventory phase, the facility was split into 7 infrastructures - electrical, external, fire, IT, mechanical, public health and structural – and materials and sub-components were calculated. Each material/component/system was then modelled with LCI data predominantly from the Ecoinvent and USA Input Output 2002 Databases. The Life Cycle Impact Assessment was then carried out using Eco-indicator 99 (Hierarchist weighting set). The results are shown in Section 0 as weighted single scores with dimensionless units – Eco-indicator points – where 1000 points represent the impact of 1 average European in 1 year.

3. RESULTS

Table 1 below shows that the impact on each of the three damage categories is highest in the operational phase of the data centre – accounting for 91.8% of the overall impact. This result is no surprise as it reflects the high operational energy consumption of data centres. However, when the results are broken down further into the various environmental impact categories that contribute to these overall loads (see Figure 1 below); impacts on the ozone layer (69.9%), ecotoxicity (54.8%) and minerals (99.1%) are found to be greatest during the embodied phase, with carcinogens also registering a high percentage nearing 45%.

It should, however, be noted that whilst the percentage contribution is higher in the embodied phase, the overall points (not presented here) for each of these impact categories are actually much lower (<3 Pt) than the greatest operational impact – respiratory inorganics (119.7 Pt) and fossil fuels (173.0 Pt). Nonetheless, this does not mean the results have no significance. The aim of the study was to understand environmental 'hotspots' within each impact category and not to omit stages and impacts because of the domination of operational energy consumption. Indeed, based on the facility total IT power of 12,895 kW, the total embodied impact (33.77 Pt) is equivalent to that of 435 average Europeans every year.

Table 1 Weighted points per damage category for the data centre (per kW of IT per year)

		Embodied		Operational	
Damage Category	**Total**	**Pt/kW/yr**	**Europeans/yr**	**Pt/kW/yr**	**Europeans/yr**
Total	408.5	33.77	435	374.8	4833
Human Health	213.6	20.40	263	193.2	2491

Resources	10.88	2.265	29.2	8.619	111
Ecosystem Quality	184.0	11.11	143	172.9	2230

Figure 2 shows in more detail the manufacturing stage of the life cycle. For every impact, except ozone layer depletion, it can be seen that the IT infrastructure plays the biggest role in the overall impact (85.7%); of which the servers contribute the highest proportion (94.9%). The biggest contribution to this load comes from a number of energy sources as well as: the tin used in IT chassis, transistors and printed wiring boards; copper, used in cabling and IT equipment; and palladium which although used in small quantities in electronic circuitry, is highly energy intensive in its extraction.

A final point to note is the large contribution of the mechanical infrastructure to the impact on the ozone layer, which highlights a limitation of using EIO. The free cooling (which is refrigerant-free) was modelled using the Air Conditioning economic sector from the year 2000 when ozone depleting refrigerants were potentially still in use. This therefore provides an average impact for a sector that includes refrigerant-based technologies. When coupled with the high cost of using a novel technology, it is likely this result is an over-estimate. This assumption will be checked in more detail in a future sensitivity analysis.

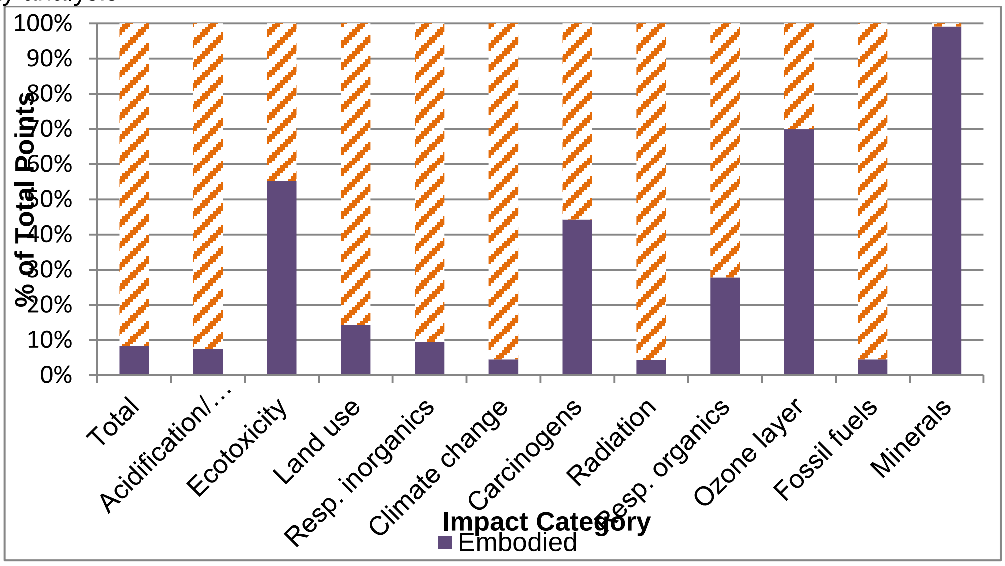

Figure 1 Weighted environmental impacts for the data centre per impact category

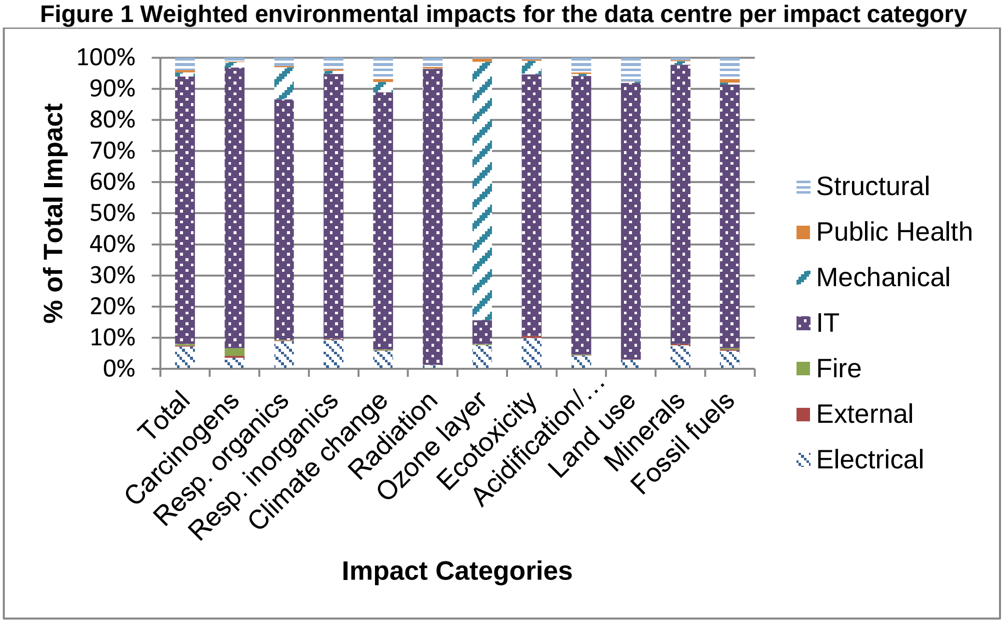

Figure 2 Weighted environmental impact due to manufacturing per data centre infrastructure

4. CONCLUSIONS

The results highlight the dominance of the operational phase in the overall environmental impact of the data centre. However, further disaggregation of the results shows the impact on mineral depletion is almost exclusively (99.1%) due to the embodied phase, whilst impacts on the ozone layer and ecotoxicity are also greatest during this stage. Moreover, IT accounts for around 80% of these embodied impacts of which servers are the biggest contributor.

The findings introduce a highly significant area of discussion. As well as impacts on the embodied phase, the IT equipment consumes the most energy in operation. This energy can be reduced in a number of ways by: improving server efficiency (50% of their total power is used simply when idling) and consolidating multiple applications onto single servers. Doing so, however, would not only decrease energy consumption, but could also reduce server numbers. Applied alongside efforts to increase time between refresh (currently 3 years), and the efficient design of servers (to reduce material consumed per unit, and enable disaggregation of the constituent parts at the end-of-life) could result in significant improvements in the impact of the IT infrastructure, both embodied and operational.

A preliminary Monte Carlo analysis found a relatively high level of variance (46.8%) in the single score result. This process highlighted areas of high uncertainty which were further checked using sensitivity scenarios where: server numbers, energy use, transport distances, choice of cooling technology, and energy mix were altered. In all cases, the same pattern of 'hotspots' were found apart from when a number of scenarios were combined. The results showed that when the number of servers were increased (increased refresh rate), but their overall efficiency was improved, hence reducing energy consumption, and a Swedish energy mix was used, the total embodied impact was almost double the operational.

Though further work is required here to verify these results, they present a compelling picture and highlight the dangers associated with omitting LCA studies from determining the environmental impact of data centres. Crucially, the work shows that when considering such large facilities, it's imperative that operational metrics are not used as a proxy for sustainability and that improvement to one life cycle stage is not made in isolation from other life cycle stages in order to ensure all impacts – positive and negative – are understood.

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