 https://doi.org/10.1051/e3sconf/202234911008

The Circular Data Centre Compass – modelling and assessing data centre sustainability

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Abstract. Data centres (DC) house electrical and electronic data processing and storage equipment. The data centre industry has grown from zero in the late 1980s into a global service provider with over 7 million sites in 2021. This rapid sectoral growth presents many challenges to environmental, social, and economic sustainability including the generation of large quantities of e-waste, (which is exacerbated by an under-developed recycling infrastructure, and a limited market for second life products) and potential threat to material supply chains, specifically Critical Raw Materials. There is an urgent need to improve sectoral sustainability, which includes development of a Circular Economy. The CEDaCI (a Circular Economy for the Data Centre Industry) project was launched in 2018 to initiate this by demonstrating its viability though business case studies, physical prototypes and digital tools, a key example being the Circular Data Centre Compass (CDCC) – a unique online tool that includes original primary source data. This tool allows users to compare and assess the overall life cycle sustainability of different servers, the criticality of embodied materials and the circularity of current and proposed designs. Therefore, the CDCC improves overall life cycle management of data centres, which increases supply chain security and reduces risk of DC service interruption.

1 Introduction

Modern computing began during World War II when it was limited to scientific, research, academic, and government establishments. Since the introduction of the World Wide Web in 1989 however, digital computing and communication has become ubiquitous and about 60% of the global population (4.6 billion people) are now 'connected' [1]. Connectivity has become essential to business and commerce, leisure and entertainment, education, and healthcare sectors for example, and in addition to people, products are connected via the Internet of Things (IoT).

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The data generated by these activities are processed and stored in data centres, which could be cupboard-sized or – like the hyperscale centres run by Facebook and Google – equivalent in area to 93 football pitches. There are over 7 million data centres around the world and although the number of individual centres is decreasing, floor area and service provision is increasing to manage on-going growth in data traffic which is currently around 4.2 trillion gigabytes per year [2]. In 2018, it was predicted that service provision would increase by 300% in Europe and by 2030, it will increase 500% globally and consequently so too will the volume of equipment [3]. The scale and speed of sectoral growth is unprecedented, as is the increasing reliance on the services it provides.

To date the Data Centre Industry (DCI) has focussed on providing uninterrupted 24/7 service and although businesses have considered economic sustainability, little attention has been paid to environmental sustainability beyond energy efficiency, and social sustainability has attracted even less consideration. The sector consumes about 1% global energy and carbon emissions are equivalent to those from the pre-Covid airline industry [3]. Although operational energy efficiency has been driven by legislation, a number of DC operators have also opted to use renewably generated electricity and/or to locate in cooler geographical zones (such as the edge of the arctic circle) to reduce energy for cooling [4]. However, until recently attention to the impacts of hardware – physical resources, manufacturing processes and treatment at end-of-life (EoL) – has been limited or omitted and consequently the DCI contributes directly to the growing volume of global e-waste, and indirectly to potential supply chain instability and disruption, because data centre equipment includes 10 Critical Raw Materials. The very rapid sectoral development and expansion means that data centre equipment was not designed for anything other than single life use i.e. they were designed for a linear economy (LE), maximising sales volume and turnover, and without consideration of factors associated with the circular economy (CE) such as easy and economical upgrade, repair, remanufacture or recycling at end-of-life. This means that many items are either removed from service and stockpiled as 'zombies' (because owners are concerned about data security) or sent for recycling. However, development of e-waste recycling infrastructure has not kept pace with that of the data centre and other electronics industries, and consequently global e-waste from which materials are un-reclaimed is growing rapidly. Furthermore, current recycling and reclamation of materials is limited to those with highest economic value (copper, iron, aluminium, gold, silver, and platinum) and therefore many other Critical Raw Materials are lost [5].

The CEDaCI project - A Circular Economy for the Data Centre Industry - was launched in 2018 to initiate a sectoral CE by raising awareness of the potential risks associated with current practice, and developing and proposing strategies, solutions, case studies, and prototypes to demonstrate the viability and benefits of circularity. The project uses systemic and whole-life thinking and is addressing all life cycle stages; a holistic approach is critical to the development of a CE, so CEDaCI also brings together representatives from all DCI subsectors so that they and the project team can learn from each other, and ensure that the output addresses current and future sectoral requirements. One of the key outputs is the Circular Data Centre Compass, a free online tool developed to educate and support decision makers in their choice and procurement of data centre equipment, and to inform the rest of the sector and wider electronics industry about the Life Cycle Sustainability of electrical and electronic equipment. Use of the tool also has the potential to significantly improve and enhance Life Cycle Management and it is now described in more detail.

2 CDCC - the Circular Data Centre Compass

The CDCC tool is designed to support decision making now and in the future. It is comprised of three main elements linked to three key life cycle stages namely Compare (which assesses

 https://doi.org/10.1051/e3sconf/202234911008

and compares the impact of ‘second life’ and new products), End-of-Life (which assesses and compares the impact of various EoL scenarios), and the Ecodesign Evaluator (which allows the user to assess, compare, and benchmark the circular potential of different design proposals).

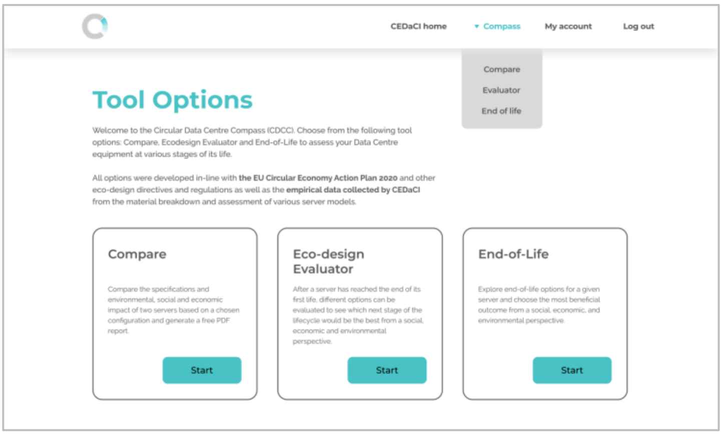

Fig. 1. The Circular Data Centre Compass tool options

The tool currently focuses on servers, which are essentially computers without monitors that process and store data. They include a number of complex electronic components such as PCBs and either hard disk or solid state drives, and consequently they have a higher embodied impact than other DC equipment [6]. Server life span is also shorter than that of other DC equipment: for example, networking equipment life can be 20 years while average server life is 3-5 years although it can be as brief as a year. Sometimes server components are upgraded and replaced in situ, but a ‘refresh’ usually involves replacement of the whole piece of equipment with a completely new product. This frequent replacement is in line with developments in chip technology, the computing speed and capability of which doubles approximately every two years.

Many servers are retired and replaced when they are still fit for purpose, which could be reused in the same organisation or alternative organisation but with different technical requirements. However, there are many misconceptions about ‘second life’ products – e.g. they are less energy efficient than new servers, they are not as reliable or durable as new servers and will not meet business needs – which deter customers. Many server owners are also anxious about data security and insist that storage drives are destroyed rather than sanitised. Sanitisation ‘wipes’ disks and they can therefore be reused or recycled relatively easily because components are intact and can be separated; destruction involves shredding in which case components and materials are all mixed together meaning separation is very challenging because ferrous and magnetic materials stick together, and therefore increases the complexity and cost of reclamation. Consequently, sanitisation is the preferred process.

The tool was developed by the CEDaCI partners, and it is distinct from other tools, the input data for which are either secondary source and/or based on assumptions. The CDCC includes a very high percentage of primary source data, which were collected by reverse engineering real products to build inventories; it also includes original data collected via new experimental CRM recycling and reclamation processes. Where primary source data were unavailable, data from Ecoinvent were included. SimaPro v 9.1 was used to support environmental impact modelling; the UN/GRI criteria were used for S-LCA modelling, and the standard Life Cycle Costing method, that includes fixed and variable costs from purchase to disposal, were used to model social and economic factors and impacts, respectively.

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Furthermore, unlike other tools that just measure carbon and its equivalents, the CDCC is a genuine comprehensive Life Cycle Sustainability Assessment (LCSA) tool that measures the impacts of thousands of different inputs. It also presents results in an accessible disaggregated format that allows users to see and compare environmental, social, and economic impacts, and materials criticality as separate sets of results so they can base their decisions on business / organisational priorities.

2.1 Compare option

Product life extension is critical to conserving resources, and reducing e-waste, environmental and social impact until and following the development of a fit-for-purpose recycling infrastructure; use of 'second life' products that have been repaired, upgraded, refurbished, and/or remanufactured can also be economically beneficial to the user.

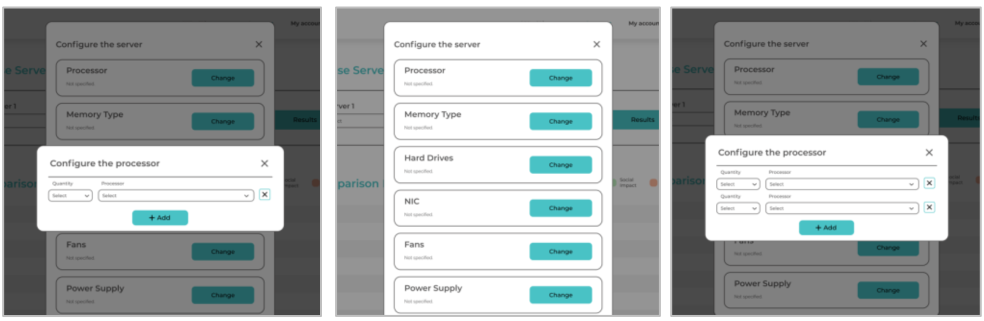

Fig. 2. The Compare interface

The Compare option allows users to replace old with new components in line with their technical requirements; these models also include robust primary source operational energy consumption data from the Interact tool and project [7] because energy consumption varies according to utilisation, server type, and age; inclusion ensures that the models are comprehensive, and results are accurate.

2.2 End-of-Life option

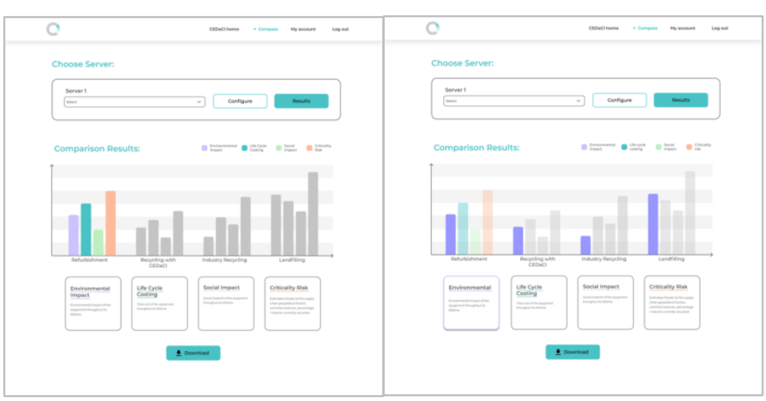

Fig. 3. Presentation of the End-of-Life Results

The CDCC also encourages more sustainable considerations once a server reaches the end of its usable lifetime for a given user. In this case, the user can select (a) refurbishment/reuse; (b) recycling via current industry methods (with limited materials reclamation); (c) recycling via the CEDaCI method (that includes reclamation of CRM and other materials including Ag, Al, Au, Ba, Ca, Co, Cr, Cu, Dy, Fe, In, Mg, Mn, Mo, Nd, Ni, P, Pb, Pr, Sb, Si, Sn, Sr, Ta, Ti, W, Zn, and Zr); or (d) sending to landfill (this is not advised but included to highlight the benefits of recycling and reuse). Furthermore the user can either compare the impact of various sustainability categories or compare the impact of different EoL scenarios.

2.3 Ecodesign Evaluator

The final feature – the Ecodesign Evaluator – allows users (and specifically designers) to assess the extent to which a physical product or design concept meets criteria for circularity. This option includes various criteria that align with those in the EU Circular Economy Action Plan [8] and similar EU directives [6, 9]. The tool is comprised of 12 main categories (including: Power Specifications, Availability of Instruction Manuals, and CE & Environmental Considerations), each of which includes a number of sub-categories (examples include: Availability of Spare Parts (after End of Sale)/Security updates; and Information about country of origin and source of materials). Responses are in bands and results are displayed as a spider diagram which allows users to calculate and compare the circularity of two products simultaneously; the user can also adjust criteria in real time, and assess whether changes are beneficial or not.

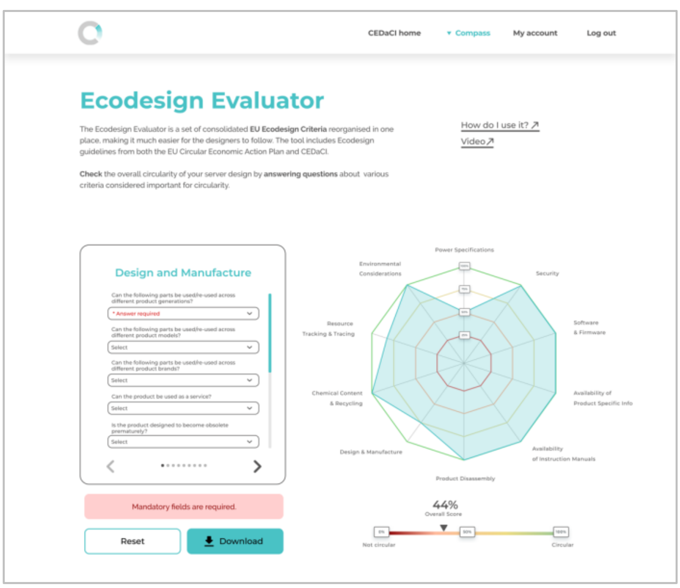

Fig. 4. The Ecodesign Evaluator

3 Conclusion and recommendations

The CDCC is being developed to encourage sustainability in the data centre industry by informing stakeholders about – and enabling them to compare – the environmental, social, and economic impact, and criticality of embodied materials in servers. This empowers the industry to make informed decisions about procurement and DC operation based on accurate models and results rather than assumptions; use of the CDCC will directly improve and enhance life cycle management, and indirectly extend product life and reduce e-waste. It will also conserve energy and physical resources, which contributes to the development of a secure supply chain and reduces risk of interruption to DC services and/or economic instability. The CDCC will be maintained directly throughout the CEDaCI project; however, the range of server brands, generations and models is continually growing and therefore data collection must continue after the end of the project to ensure that the tool remains current and as accurate as possible. The various LCSA and Criticality models must also be updated as new data become available.

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