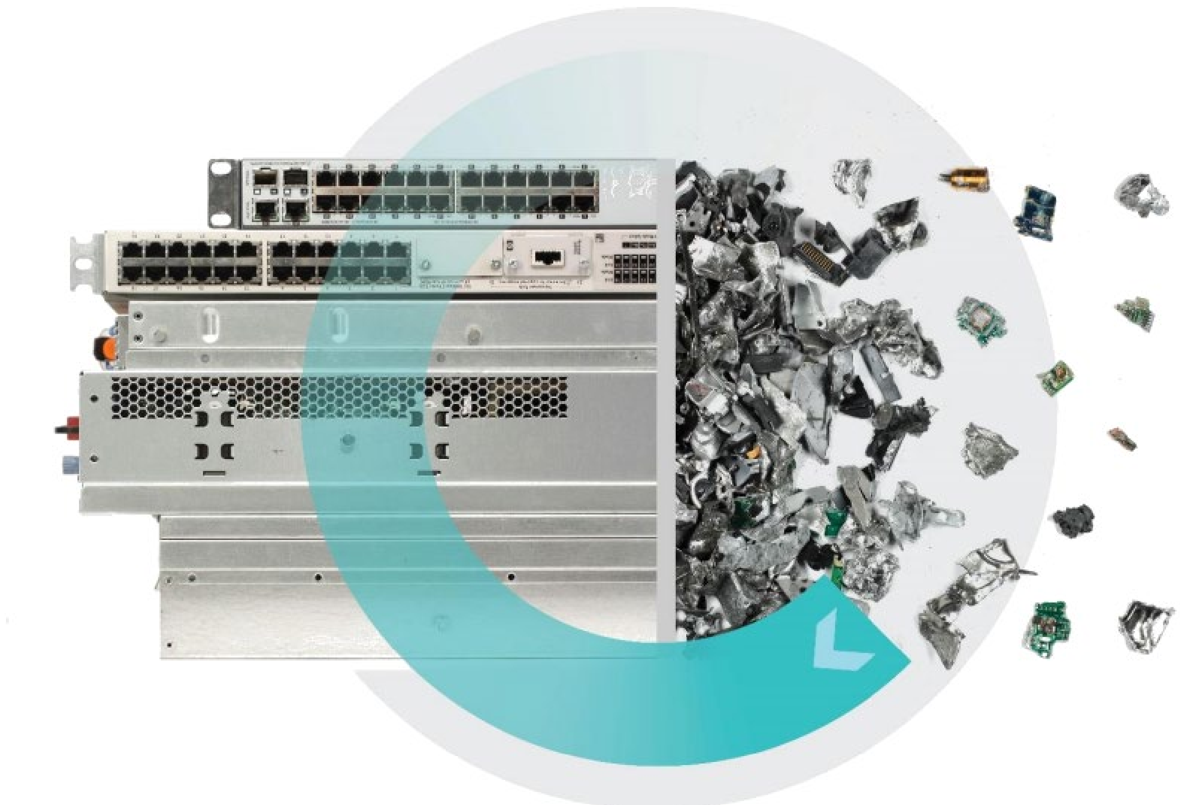
CEDaCI Project:

Policy and Strategy Document



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CONTENTS

SUMMARY

This document sets out the broader policy context relating to circular economy, in particular those instruments most relevant to data centres. It explains what data centres are and the economic and infrastructural role they play, and sets out the combination of sustainability opportunities and challenges they present for policy makers.

The paper then explains the objectives of the CEDaCI project in addressing some specific barriers to implementing circular economy principles within the broader data centre sector. In particular, organisations seeking to review, refresh or dispose of their computer server estate on the open market need to make informed choices that take into account circular economy credentials. However, many, especially SMEs, lack the specialist technical expertise required.

The paper summarises the activity and deliverables of the project to date and explains the rationale for the specific focus on computer servers. One key deliverable, a bespoke, entry-level decision making tool – the CEDaCI Compass – aims to ensure that circular economy is a factor in such decisions and provides reliable data to assist with such decisions. This document explains how this tool works and also identifies some of the challenges that had to be overcome when developing the tool and consider how these were resolved, or might be addressed in future.

The document also reviews some of the initial findings from applying the decision making tool in practice and uses these to explore how the tool can be deployed to support best practice within the industry. The paper considers how the application of the tool can support existing policy initiatives and also explores whether the findings have revealed the need for further policy measures to drive circular economy best practice within data centres.

SCOPE

The CEDaCI project addresses barriers to implementing circular economy practices in the data centre sector. The specific focus is on computer servers, where asset life is relatively short, where there is a large, commoditised market and where the implementation of circular economy measures varies significantly across the industry. While we are seeing closed loop manufacturing models being adopted by some by some sub-sectors of the data centre market, primarily large cloud service providers, there are other parts of the market struggling to apply circular economy principles to their server estate. The CEDaCI project is targeted at identifying and addressing barriers in these areas, where organisations, especially SMEs, buy – and sell - servers on the open market.

Currently, servers tend to be purchased on the basis of processor performance and energy efficiency rather than broader sustainability credentials and to date there has been no systematic means of comparing the circular economy credentials of servers at point of purchase. Organisations also struggle to make informed decisions about existing stock, whether to retain, sell or recycle, usually because they lack specialist expertise or do not recognise that these decisions need to be made strategically.

There also factors that can discourage companies from purchasing refurbished or remanufactured servers in preference to new models – such factors introduce artificial barriers to the more widespread adoption of circular economy practices and models in the industry.

The CEDaCI Project tackles some of these barriers by better informing decision making relating to servers.

QUICK OVERVIEW OF THE CEDaCI PROJECT

The CEDaCI Project is an Interreg North West Region part funded European project running from 2018 to 2023. It is focused on improving the adoption of circular economy principle and practices within the data centre industry, specifically the commercial computer server market. The data centre sector has grown rapidly, driven by ever-increasing demand for digital services across the wider economy. In parallel, the need for computer hardware, primarily servers, has also expanded very significantly and continues to grow. In view of the relatively short asset life of servers, there is concern that volumes of e-waste are increasing and at the same time, resources and materials are being depleted.

The CEDaCI project conducted three pilot projects on design and manufacture, life extension –- second life and refurbishment, and end of life – recycling. Outputs include a Life Cycle Assessment (LCA) database and methodology, a Decision Making Tool – the Circular Data Centre Compass, Improved refurbishment, recycling and reclamation strategies and business models, and circular economy eco-design guidelines for servers.

Through a novel reverse-engineering approach a variety of servers have been dismantled down to component level, and empirical data has informed lifecycle assessments. As a result, the CEDaCI project has been able to put real numbers against sustainability and cost criteria. This differentiates the project from previous approaches which tend to rely on modelling and assumptions. What this means is that the project can set out sustainability indicators and relative costs for options like retention, refurbishment and recycling that will provide a reliable indication of the business case for whichever course of action is under consideration.

To further aid decision making, and using the empirical data from real servers, the CEDaCI project has developed a bespoke, entry-level decision making tool – the CEDaCI Compass - to ensure that circularity is a factor in such decisions.

The CEDaCI project is squarely focused on identifying ways to improve the adoption of circular economy principles within the data centre sector, specifically relating to commercially available computer servers traded on the open market. The project has multiple objectives which include:

- To assess the current situation with respect to the application of circular economy practices in the European data centre industry. and characterise the material composition of computing hardware.
- To conduct a screening LCA covering all life cycle stages of computing hardware (except use phase) to identify environmental hotspots.
- Undertake an economic assessment of full dismantling to assess whether there is a business case for a new market entrant to achieve higher material recovery through full dismantling and redistribution of waste streams.
- Synthesise and present this research in a Situational Analysis Report[i]
- To bring together stakeholders from all equipment life cycle stages to ensure that waste becomes useful resource, that energy is minimised and materials remain available for continued use.

- To develop a decision making tool that helps organisations make informed choices about the circular economy credentials of computer servers, enabling them to compare products against a number of sustainability criteria relating to lifecycle impact and circularity.
- To provide entry level training for SMEs to assist their strategic decision making regarding server purchase or disposal.
- To identify how the decision making tool can contribute to existing policy initiatives and explore the potential for further measures.

The broader aims of the CEDaCI Project include:

- Extending product life through second use and refurbishment
- Increasing dematerialisation through improved EcoDesign guidelines
- Increasing WEEE collection, processing and ecycling in the EU
- Promoting adherence to EU regulations
- Creating jobs in North West Europe
- Limit stockpiling of resources overseas
- Improve transparency of WEEE disposal supply chain and ensure compliance
- Improve transparency of data centre sector materials, manufacture and supply chain

More information about the CECaCI Project is available on the website here:
https://www.cedaci.org/

WHAT IS THE CIRCULAR ECONOMY?

The term "circular economy" has become a very familiar one over the last few years. Although not a new concept, it presents an alternative to the traditional "make-use-dispose" approach that still applies – predominantly though not exclusively - to manufacturing and commerce.

Circular economy principles are attracting growing attention from many other stakeholders. These include policy makers, where the agenda has moved away from an almost exclusive focus on waste to accommodate more geopolitical concerns about resource scarcity and resource security. The circular economy is well established as a policy priority in Europe following the launch of the Circular Economy Package in 2015 and multiple activities to strengthen its measures and broaden implementation.

Broadly speaking, a circular economy is one in which there is no such thing as waste. In the natural environment we have examples like the nutrient, carbon and water cycles: minerals are released from rocks, taken up by plants and other organisms, released with the help of detritivores after death and taken up again, or laid back down as sediment which then returns to rock. Proponents of the circular economy seek to learn from and mimic this seamless, waste-free approach to resource management. The European Commission provides a useful description that suggests the direction that policy is heading on this agenda:

*"The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the **life cycle of products is extended.** In practice, it implies **reducing waste** to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby **creating further value**. This is a departure from the traditional,* linear *economic model, which is based on a take-make-consume-throw away pattern. This model relies on large quantities of cheap, easily accessible materials and energy. Also part of this model is planned obsolescence, when a product has been designed to hav e a limited lifespan to encourage consumers to buy it again. The European Parliament has called for measures to tackle this practice."*

The Ellen MacArthur Foundation provides a more comprehensive definition:

"A circular economy is an industrial system that is restorative or regenerative by intention and design… it replaces the "end of life" concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair re-use, and aims for the elimination of waste through the superior design of materials, products, systems and within this, business models. Such an economy is based on few simple principles. First, at its core, a circular economy aims to design out waste. Waste does not exist – products are designed an optimised for a cycle of disassembly and re-use. These tight component and product cycles define the circular economy and set it apart from disposal and even recycling where large amounts of embedded energy and labour are lost. Secondly, circularity introduces a strict differentiation between consumable and durable components of a products. Unlike today, consumables in the circular economy are largely made of biological ingredients or "nutrients" that are at least non-toxic and possibly even beneficial and can be safely returned to the biosphere – directly or in a cascade of consecutive uses. Durables such as engines or computers, on the other hand, are made of technical nutrients unsuitable for the biosphere, like metals and most plastics. These are designed from the start for re-use. Thirdly the energy required to fuel this cycle should be renewable by nature, again to decrease resource dependence and increase system resilience…."

There are powerful drivers for pursuing a circular economy: although a circular approach may not be a feasible solution in every circumstance, the conventional *take, make, use, dispose* route cannot continue to be the dominant economic model – not just from a waste management point of view but also because of the growing issue of resource scarcity, and a burgeoning global middle class can only add more pressure at both ends.

Key players in the circular economy

Circular economy terminology was brought to prominence by the work of organisations like the Ellen MacArthur Foundation in the UK, following the "cradle to cradle" concepts established by William McDonough and Michael Braungart. The Foundation articulated the environmental and economic benefits of the concept in 2012 with follow-up reports in 2013 and 2014. Other organisations across Europe were also active in this space and policy makers within the European Commission and beyond have identified the circular economy as a policy priority and are taking action accordingly to alert businesses and other stakeholders to the urgent need for a more circular approach.

Many contributors see the circular economy not as an end in itself but as a framework that brings together different elements into a coherent landscape and accommodates existing practices such as lifecycle thinking, ecodesign and resource efficiency alongside new approaches. Some observers see the circular economy as simply a new means of describing ways of working that are already well-established – such as cradle-to-cradle, closed loop, service delivery and leasing models.

Policymakers are seeking to understand where breaks in this cycle occur, why they occur and whether policy instruments can be effective in bridging them, either temporarily or permanently, and how to avoid perverse incentives and unintended outcomes, for instance from a disproportionate focus on recycling quotas. Collectively we need to do a better job of joining up pull and push factors so that businesses can understand the opportunities that a circular approach presents and confidently take steps to deliver commercial offerings that accommodate circular economy thinking and practice.

Over the last five years there has been a welcome change of focus from purely a consideration of how we perceive resources and "design out" waste to how we derive economic value from a more circular approach. There is a rapidly growing body of literature on the economic opportunities presented by circularity[ii], including figures for job creation. Many initiatives now focus on the market opportunities for businesses, others are trying to quantify the macro-economic contribution that a more circular approach might contribute to national and regional economies. This change in emphasis is also explicitly supported by NGOs and business groups.

WHAT IS A DATA CENTRE?

Data centres[iii] are highly resilient facilities that underpin our modern economy by processing, managing, storing and transacting digital data and, with communications networks, form our core digital infrastructure[iv]. A data centre essentially consolidates organisational IT functions. It should provide a secure, resilient, and controlled environment for IT equipment (servers and networks) and supporting hardware and be equipped with guaranteed power supply and high bandwidth connectivity. Redundancy (duplication) of networks, power and other infrastructure ensures continuity. Building management controls such as air conditioning maintain environmental conditions for the equipment within a specified envelope of temperature and humidity, and advanced security systems ensure that the facility and its data remain secure. A data centre may be on-premises or remote. It may be purpose-built or be part of an existing building. It may be operated in-house to support organisational IT functions or by a commercial third-party provider. It may be dedicated to one organisation or service multiple customers.

Data centres support every conceivable part of our modern economy: business processes, Government services, telecommunications, transport infrastructures and social networks all depend on computers interacting in this way, exchanging digital information. Data centres enable retailers and banks to process financial payments, supermarkets to resupply, delivery companies to manage logistics and public authorities to deliver services and messaging. They provide the technical infrastructure for financial services, aerospace, transport, healthcare, retail and utilities. Some sites are officially deemed CNI (critical national infrastructure) to reflect the nature of the activity being managed therein. Each new data centre contributes between €470M- €520M to the economy[v] while that of each existing data centre is estimated to lie between €350M and €380M per annum.

While it is broadly acknowledged that data centres form an important part of our infrastructure, and are critical to economic growth, the act of consolidating IT functions makes them energy intensive. Collectively data centres consume around 1% of global electricity according to the International Energy Agency[vi] and are thought to represent around 20-25% of the ICT sector's energy consumption (telecommunications networks account for 25-30% with the rest, over 50%, attributable to end user devices). REF . Data centre energy use tends to be the subject of much mythologising and exaggeration and there is no basis for the frequently cited claim that the sector emits as much carbon dioxide as the airline industry[vii].

Data centres therefore present an unusual array of sustainability challenges for policy makers. On the one hand they underpin and enable a vast range of energy saving technologies, from transport logistics to smart grid, and facilitate the dematerialisation of traditional, carbon intensive business models. The process of digitalisation, and the many sustainability benefits it will deliver, depends on data centres. So we have to ensure that data centres are themselves operated sustainably and this is further complicated but the variation in type and business model currently in operation across the sector.

Estimates for the number of data centres varies, depending on how they are defined. Within the UK, for instance there are around 500 recognisable facilities, of which around half are commercial providers. Globally there are tens of thousands of data centre. A "recognisable facility" tends to have a minimum power supply of 240KW, a floor area of over $200M^2$, environmental controls and operational redundancy including emergency back-up power to allow continuous running.

Adding up data centres is complicated by the fact that there are different types of data centres. The very largest sites, called hyperscale, are run by large, multinational cloud services providers. These operators benefit from economies of scale and their facilities tend to be highly efficient. They also operate at a scale that enables them to run closed loop manufacturing and develop significant technical expertise.

Then there are colocation data centres, that provide the data centre infrastructure for third party customers. Most of these are run by large commercial operators. These are called “colocation” as customers usually lease space in which to deploy their own IT hardware, “colocated” with the servers of other organisations. Reasons for outsourcing include security, resilience and cost: data centres are eye-wateringly expensive to build and maintain, especially for organisations where they are not part of the core business offering. However, colocation providers, unlike hyperscale cloud operators, do not own the servers within the facilities – these belong to their customers.

Then there are data centres that organisations run data centres to provide digital services to third parties –IT service providers and telecommunications providers. The remainder are dedicated facilities, supporting corporate IT functions and customer services for organisations like banks, retailers and universities. These are known as “enterprise” facilities because they are dedicated to supporting the business; the enterprise. These may be on-premises or remote from the business. The business that own and operate these dedicated facilities tend to own the servers within them. Many organisations mix and match – outsourcing mission critical activities but keeping more mundane functions in-house – or vice-versa.

Some organisations do not consolidate their IT into purpose built or dedicated data centre facilities. Instead they run smaller data centres or server rooms on premises. IT that is kept in server rooms, closets and cupboards is known as “distributed IT” and should not be classed as data centres: in reality distributed IT is the polar opposite of data centres, which consolidate functions into purpose-built facilities. Nevertheless it is sometimes mistakenly included in data centre tallies. Any estimate for data centre numbers that runs into millions has included every server room and cupboard in the count, despite the fact that they are certainly not data centres. Unfortunately there are no formal criteria that differentiate a data centre from a server room- although steps are already underway at Commission level to develop formal definitions - but broadly speaking, a combination of power supply, resilience and server capacity is used.

However, while is it incorrect to classify server rooms as data centres in terms of numbers, this cohort, together with small on-premise data centres, is both significant and problematic from a sustainability perspective, including circular economy considerations. While the trend is towards outsourcing and consolidation, it is thought that around 50% of activity may still be on premises in this form. This is problematic because there is no transparency and few if any reporting obligations applied to these facilities. Moreover they are unlikely to be run as business units or obliged to meet performance KPIs and so may be less incentivised to optimise energy use. This cohort may lack specialist technical knowledge regarding the management of server estate and also may lack the commercial incentives that would drive elements of sustainable decision making like energy stewardship and server procurement and disposal.

The fact that small facilities lag behind in terms of sustainability is supported by evidence from the EURECA project in 2018[viii] which analysed around 350 small on-premise public sector data centres in 2018 and reported average PUE[ix] of around 5. So for each KWh used by the IT, there is a facility overhead of 4KWh. Compare that to PUE in the colocation sector which according to the CCA data is around 1.7, giving therefore a facility overhead of 0.7. So at an infrastructure level the on-premise approach to computing is roughly six times less efficient than outsourcing. The IT is similar: server utilisation (how busy the servers are) and computational efficiency (how efficient the processors are, which tends to decline with age) were also low[x].

Rapid expansion of the cloud services market is driving growth in European data centre development because cloud services are delivered either directly or indirectly from data centres. Cloud computing is essentially the process of accessing IT functions via the internet – so applications and activity are held remotely in data centres, rather than on personal devices like laptops, PCs, tablets and phones. A cloud service provider may operate their own data centre or lease space from a colocation provider and there are many different business models adopted across Europe. This infographic setting out the different business models and service offerings in the UK's commercial data centre market demonstrates the complexity of the sector and interrelationships between business models.

https://www.techuk.org/asset/207224FE-3ADC-43CB-950E4ED2533CA84B/

EUROPEAN POLICY CONTEXT

The European Commission and Parliament have long recognised the importance of a more circular economy and the opportunities it presents to create jobs and competitive advantage for Europe and ensure that our economy is more sustainable. Europe is already leading the global transition towards a low-carbon and circular economy and has already developed a comprehensive array of policy actions and associated implementing measures to make this a reality.

In 2015, the European Commission adopted the 'Circular Economy Package' an ambitious policy agenda covering all aspects of the product life cycle, which included a delivery mechanism in the form of the EU Action Plan which set out a list of concrete actions together with a timetable for completion. This package gives strategic objectives and directions to nation state governments, to businesses and to society at large, together with a clear pathway to implementation.

At the EU level the actions are intended to drive investment at nation state level, create a level playing field and remove existing obstacles in the single market. The proposals should help to drive product lifecycles towards a closed loop model by fostering more re-use and recycling.

Further policy measures were adopted by the European Commission in 2018 to implement the ambitious Circular Economy Action Plan. These included:

- Europe-wide EU Strategy for Plastics in the Circular Economy
- Communication on options to address the interface between chemical, product and waste legislation
- Monitoring Framework on progress towards a circular economy at EU and national level and
- Report on Critical Raw Materials and the circular economy.

These provisions include an indicator / monitoring framework and therefore collectively provide the means to monitor progress on the actions identified in the Action Plan and also track broader progress towards a circular economy. The indicators within the framework mostly use data already being collected but steps are also being taken in parallel to improve data quality. This indicator framework is complemented by a Resource Efficiency Scoreboard and a 'Raw Materials Scoreboard' which were developed by the Commission over the last few years.

In 2018, with the new Commission in place, the European Green Deal was announced, a strategic agenda to decouple economic growth from resource use. This hugely ambitious programme embraced the opportunity presented by the new EVP appointments to provide a strategic and coordinating role, bringing together multiple strands of policy activity in a coherent way and ensuring cross-referencing between Directorates with policy responsibilities within the sustainability sphere.

In 2019 the European Commission adopted a comprehensive report on the implementation of the Circular Economy Action Plan which was followed in 2020 by the adoption of a new Circular Economy Action plan. This is one of the key pillars of the Green Deal.

The new Action Plan aims to make strengthen competitiveness, protect the environment and enhance consumer rights. It therefore focuses on eco-design, circular economy processes and models, and encourages sustainable consumption and the retention of key resources within the EU. The Plan is explicitly part of the EU Industrial Strategy and the intention is to make sustainable products the norm in the EU and to focus effort where resource use is highest and where there is greatest potential for circularity.

Policy Timeline relating to Circular Economy measures

Year	Measures relating to Circular Economy
2015	Circular Economy Package and Action Plan
2018	Further policy measures to support implementation including a monitoring framework, raw materials scoreboard and resource efficiency scoreboard
2019	European Green Deal Adopted
2020	Adoption of New Circular Economy Action Plan
2021	New Rules on Organic Pollutants in Waste and on Waste Shipments
2022	Multiple measures, plastics, packaging, substantiating green claims and much more…

DATA CENTRE-SPECIFIC POLICY CONTEXT

The complex nature of data centres, where multiple technologies and disciplines converge, means that facilities have long been required to comply with a surprisingly wide variety of regulatory instruments. These include the Energy Efficiency Directive, the Industrial Emissions Directive, the EcoDesign Directive, the WEEE Directive and the General Data Protection Directive, plus a range of additional domestic requirements that vary between nation states. REF.

At a component level we see a combination of generic and targeted measures – for instance WEEE and EcoDesign respectively. Both are particularly important with respect to computing hardware. While WEEE targets all forms of electronic waste and therefore includes servers and networking equipment, EcoDesign requirements specifically focused on computer servers were developed under Lot 9 and continue to be reviewed, refined and extended.

At facility level, however, until recently there have been few if any policy instruments where elements are targeted specifically at data centres. There are domestic exceptions like the Climate Change Agreement in the UK which set efficiency targets for data centres which, if met, qualify operators for an energy tax discount and there have been other similar nation state initiatives elsewhere. However, at European level, The Green Deal was the first to identify specific provisions for data centres by stating that European data centres must be climate neutral by 2030 and we are now seeing much more frequent and explicit references to the sector in policy proposals and regulatory instruments.

Green Public Procurement (GPP) criteria have been developed specifically for data centres. See https://publications.jrc.ec.europa.eu/repository/handle/JRC118558 . These are currently not obligatory but there are proposals to make them mandatory for public authorities procuring data centre services. While the GPP criteria in themselves are robust, it is critical that they are part of a process that assesses scope for consolidation, outsourced solutions and ensures right-sizing.

At a broader sustainability level approaches like the European Taxonomy and amendments to the Energy Efficiency Directive to accommodate additional requirements for data centres have significant implications for the sector and will dramatically extend regulatory scope and improve transparency.

Study On greening Cloud Computing and electronic Communications Services and Networks

Most recently the European Commission has conducted a study[xi] to identify policy measures that can improve the energy efficiency and circular economy performance in data centres and cloud computing. While acknowledging that data centres underpin digitalisation solutions that can deliver energy and carbon savings across the wider economy, it is critical that the digital sector is itself performing efficiently and sustainably. As cloud computing activity increases across Europe to deliver digital services, especially in data-hungry emerging technologies such as blockchain, artificial intelligence, and the Internet of Things, the Commission is keen to address the associated growth in energy consumption of data centres.

Key objectives included proposing policy measure to increase energy efficiency of data centres, assessing the sector's environmental and economic impacts, performing an analysis of data centre definitions and types, determining meaningful size thresholds and analysing industry standards, metrics, indicators, methods and methodologies. However, the study objectives also included specific provisions relating to circular economy, including an analysis of current market practices related to circularity and identify potential ways to increase circularity and a note that while there will be alignment to EN50600, this standard could benefit from including more circularity elements.

This has resulted in a number of key actions and priorities. Policy recommendations from the study included a requirement to make GPP for data centres mandatory, develop a European registry of data centres, and improve the EU Code of Conduct for Data Centres (see below), which provides a set of well-respected best practices but could benefit from more emphasis on circular economy measures and also lacks an adequate administrative function. The registry requirement will present an interesting conundrum because the size threshold must be set low enough to include smaller on-premise facilities where energy stewardship tends to lag far behind commercial entities, where there is no obligation to report, which lack transparency and accountability, where facilities are not run as business units and where there may be a lack of technical expertise.

During discussions on how to implement these recommendations within the industry, one issue identified is that colocation data centre providers do not own the computer hardware that they host within their facilities. It belongs to their customers. The colocation provider is highly incentivised to ensure that the infrastructure operates efficiently or they would be unable to attract customers, but they do not control the server activity. Although the predominant charging models, which reflect energy costs and therefore, server performance, should strongly incentivise customers to optimise server efficiency but if the IT functions hosted within the data centre do not represent a significant proportion of the customer organisation's turnover, these incentives will be diluted. The cost of IT functions for a bank, for instance would represent only a small percentage of turnover. Compare this to a commercial cloud services provider who is hugely incentivised to operate an optimally energy efficiency facility in order to remain competitive. For such an entity, energy costs will be a dominant element of operational costs.

A similar problem arises within smaller organisation and those that run data centre facilities, server rooms and closets on premises. Running costs are often subsumed into office costs and are not transparent. The Eureca project[xii] (see above and references) revealed very poor energy stewardship in small on-premise data centres and server rooms within the public sector. This is a major concern because these facilities are not obliged to report their data or audit performance and it is thought that around 50% of activity is still held on premises in this way. Unfortunately, many smaller organisations do not have the technical expertise to review or assess their server estate and make informed choices about new purchases, retention and disposal. So any policy tool aimed at data centres must address this unscrutinised and unreported part of the sector where we think there could be significant room for improvement across all areas of sustainability, and where greater transparency is essential.

This cohort of data centres should be exceptionally well-positioned to benefit materially from the CEDaCI Decision Making Tool.

Relevant Standards and Metrics

For a relatively young industry, the data centre sector is surprisingly well provided for in terms of bespoke industry standards, ranging from proprietary approaches like the Uptime Tier system, to international, peer reviewed public standards developed and governed by organisations like ISO and CENELEC (international equivalents IEC and ISO). The most well-known series of data centre standards - EN50600 - is a modular approach dealing with design and operational aspects of data centres and covering resilience, security and sustainability. There is also a five-tier maturity model focused on energy efficiency and sustainability.   The sector also relies on a wide variety of performance metrics, addressing elements like water consumption, heat reuse, renewable energy adoption and infrastructure efficiency[xiii]. At European level there is a dedicated group that reviews and harmonises different data centre standard relevant to sustainability.

Industry Initiatives

In terms of industry initiatives, there has been significant action on multiple fronts which is very timely in view of the increasing regulatory scrutiny that is being applied to the sector.   At European level the Climate Neutral Data Centre Pact[xiv] seeks to address Commission priorities relating to data centre sustainability. Signatories make commitments in five areas, one of which is specific to circular economy and relates to computing hardware and another that is also relevant as it relates to heat reuse. The level of engagement from the European industry is excellent, with signatories ranging from large global cloud service providers to SMEs.

At a global level, the Infrastructure Masons, a US-initiated but now fully multinational network of operators and suppliers within the sector, are focusing attention on transparency and embodied carbon.

THE CIRCULAR DATA CENTRE COMPASS

The circular data centre compass is an entry-level decision making tool designed to guide organisations to choose more circular options during the procurement, refurbishment and disposal of servers and to assess the environmental, social and economic impacts of their choices.

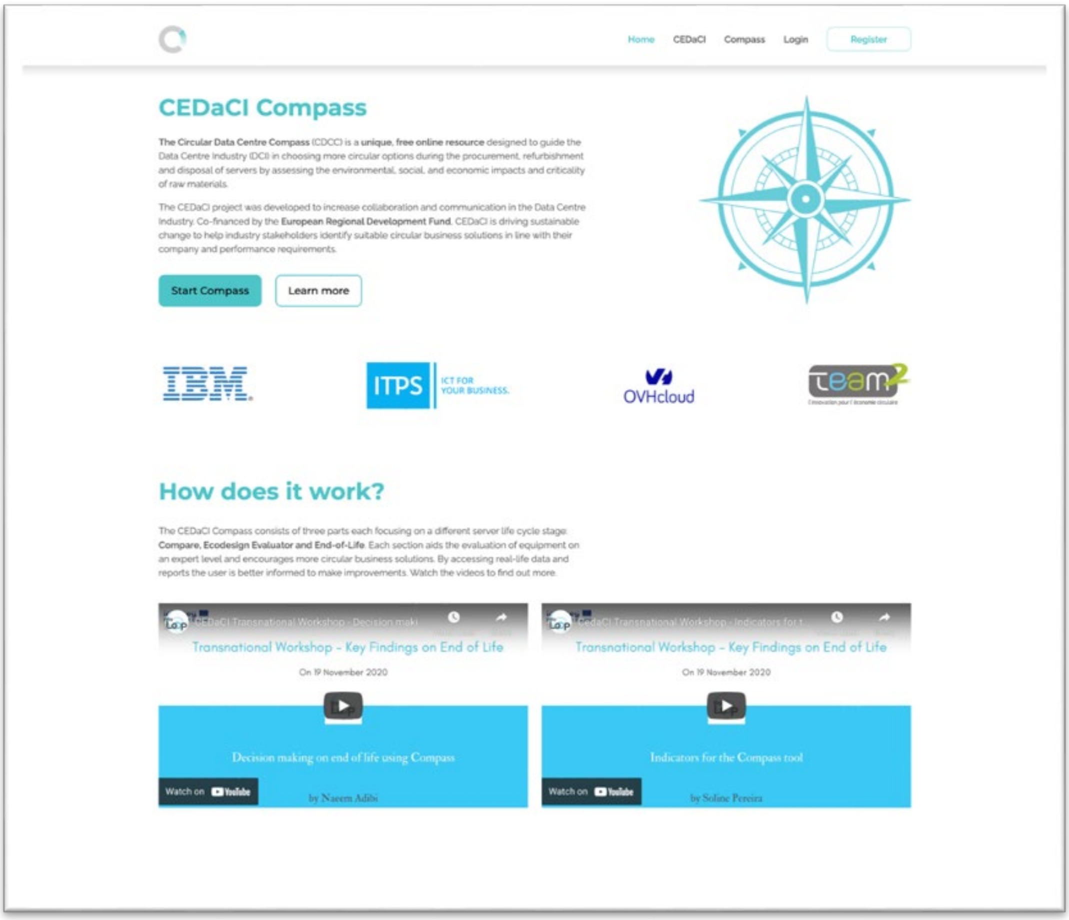

Figure 1 CDCC Homepage

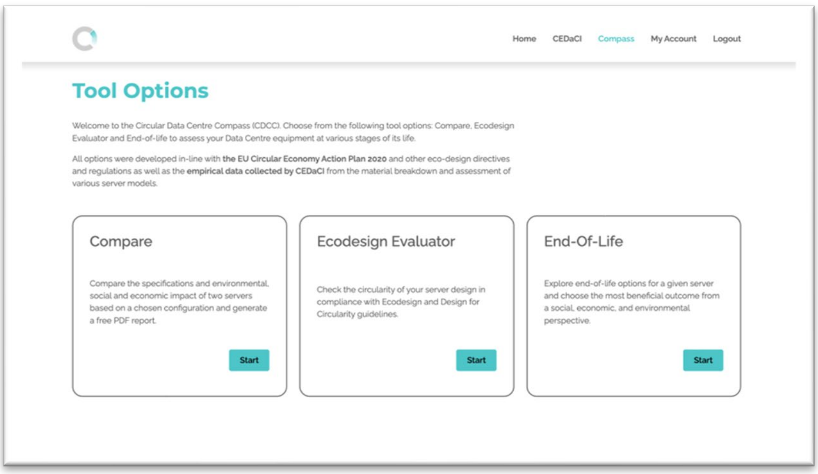

Figure 2 Compass menu: Compare, Ecodesign Evaluator and End-of-Life

All options – Compare, Ecodesign Evaluator and End-of-life - were developed in-line with the EU Circular Economy Action Plan 2020 and other eco-design directives and regulations as well as the empirical data collected by CEDaCI from the material breakdown and assessment of various server models.

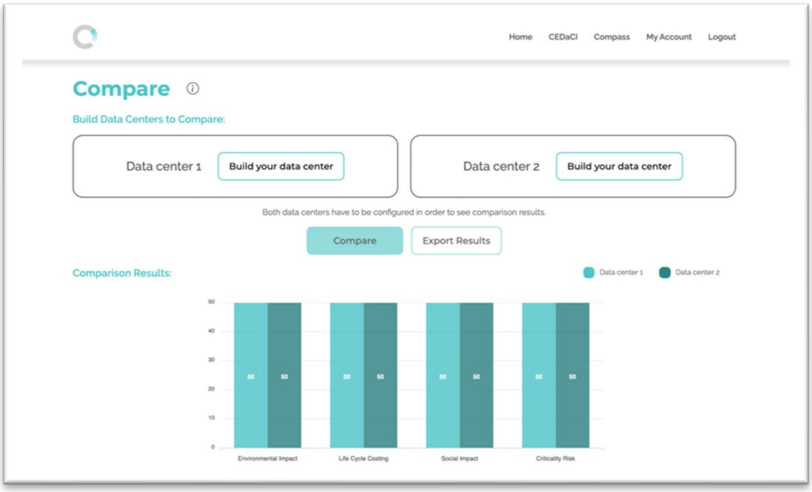

Figure 3 Compare dashboard.

The Compare tool (Fig.3) uses Life Cycle Assessment to assess the entire life cycle of the given configuration of the equipment including the extraction of raw materials, manufacturing/assembly, transportation, use and end-of-life stages. The Circular Footprint Formula is used to account for benefits and burdens, resulting from the use of secondary and virgin materials, and recycling and energy recovery.

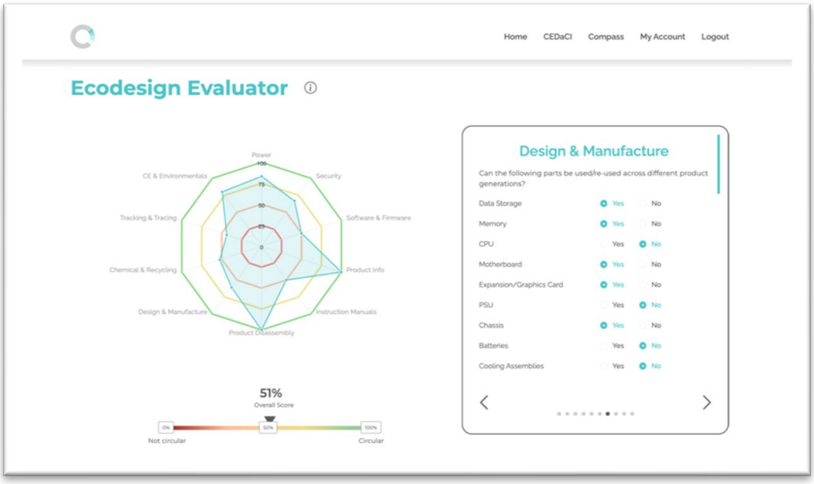

Figure 4 Ecodesign Evaluator dashboard.

The Ecodesign Evaluator (Fig.4) is a set of consolidated EU Ecodesign Criteria reorganised in one place, making it much easier for the designers to follow. The tool includes Ecodesign guidelines from both the EU Circular Economic Action Plan and CEDaCI.

The End-of-Life tool (Fig. 5,6,7) aims to encourage more sustainable considerations once a server reaches the end of its usable lifetime for a given user. The tool allows to assess and compare impacts and criticality risk of different end-of-life scenarios, including refurbishment, recycling using current industry methods, recycling using CEDaCI recommendations and landfill.

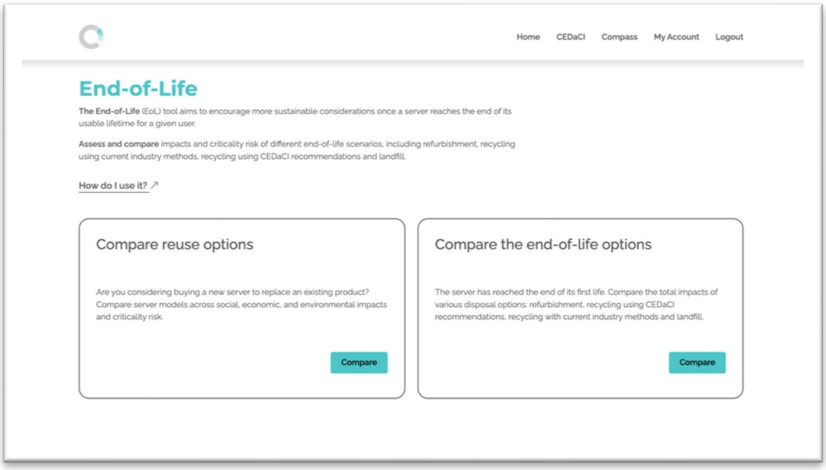

Figure 5 End-of-life tool options.

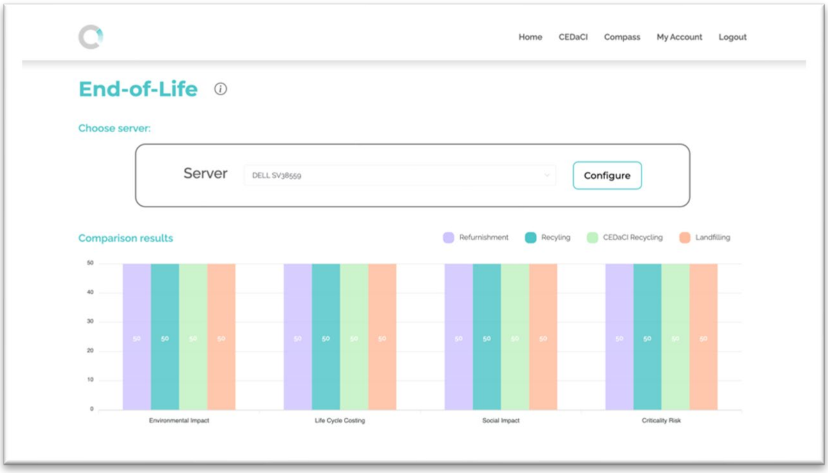

Figure 6 End-of-life dashboard.

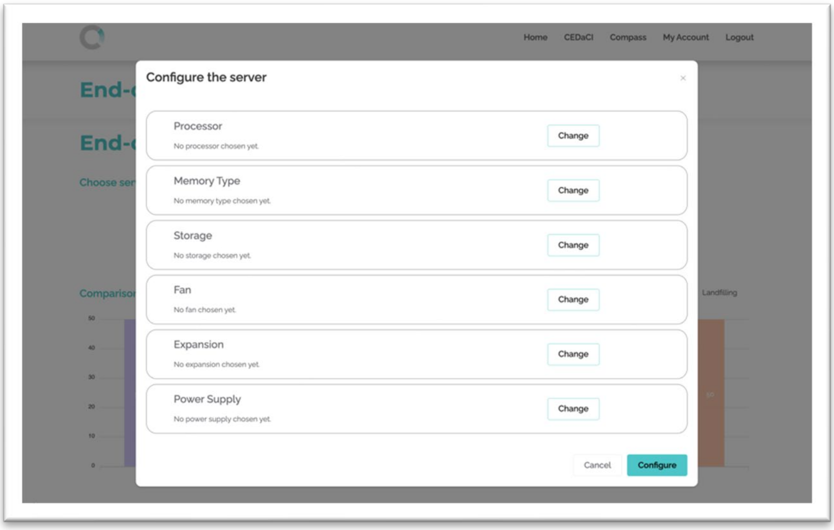

Figure 7 Configure the server window.

CEDaCI COMPASS: FINDINGS AND POLICY IMPLICATIONS

CDCC Evaluator is designed to evaluate the degree of excellence and conformity with the recommended guidelines set out by the EU Circular Economy Action Plan 2020 and other eco-design related documents that feed into it. It is designed to help the assessment of the Data Centre equipment at the design stage of its life cycle, allowing for a quick analysis of the design in line with the recommended guidelines and regulations by giving the design model an overall circularity score.

Evaluator's matrix is based on the design requirements and recommendations outlined in the EU Circular Economy Action Plan 2020, EU 2009 Eco-Design directive – 2009/125/EC DIRECTIVE and the COMMISSION REGULATION (EU) 2019/424, and includes CEDaCI proposed supplementary Eco Design Guidelines, based on the empirical data from the assessment of different server models.

Material content

There is still significant opportunity to minimise material content of computer servers. Much higher material resource efficiency could be achieved, and urgent steps should be taken to improve practice in the data centre sector.

A disassembly analysis of 16+ different server models across different server generations carried out by CEDaCI revealed only a small number of parts can be replaced and repaired. Although, the modern enterprise servers are designed for general repair and remanufacture, there is no overall design standardisation. The design tends to differ considerably between models and generations. This means that the majority of parts cannot be interchanged to prolong their use and prevents maximum reuse of the equipment. Such design approach encourages excessive manufacturing and impedes on sectoral transition to circularity. According to CEDaCI data an average server contains 3-4 different steel alloys and around 3 different polymers as well as textiles, paper, aluminium, zinc, and copper – this is related to mechanical components only, such as the chassis. In addition to the basic mechanical design, there is a number of hazardous chemicals and CRM used in the electronics as well as PM and PGM (platinum group metals). As is evident, the materials' list of a standard server is quite extensive.

Embodied energy

Data centre operations are decarbonising rapidly – initially through the procurement of certified renewable power from energy suppliers, but increasingly through other approaches that do not consumer existing renewable capacity, such as power purchase agreements, which fund additional, utility scale low carbon generation, or locating data centres next to unused power sources such as EFW - energy from waste and geothermal. In fact, data centres, using electricity almost exclusively and with unusual consumption characteristics such as high flat load, are in a better position than almost every other industry sector in terms of achieving operational net zero in the next few decades. However, as data centres decarbonise operations, embedded energy increases in importance and this will affect decisions such as server refresh, where the improved operational efficiency of a new model has to be balanced against the high embodied energy of manufacture (not to mention material intensity). The business case for re-use, refurbishment and other approaches to extending product life therefore will continue to improve over time.

The CEDaCI Compass can deliver a material improvement in informing this decision making process, with its entry level Decision Making Tool supported by guidance and the opportunity for training.

Modularity and Standardisation

The disassembly of server models revealed a surprising lack of consistency in terms of chassis and components, and a more modular approach with standardised components would be desirable.

Although hard drives, fans, power supplies, processors and heatsinks, memory, expansion card/graphic cards and the motherboard are designed to be hot-swappable they consist of subassemblies that are often not repairable. For example, fans are standard parts, but plastic casing designed to make the part be easily removed (hot-swapped), would only fit one particular fan cage within a specific server model and sometimes even generation. The plastic casing is made of fire-retardant plastic – PC-ABS-FR which is not widely recycled at present. This subassembly plastic casing is difficult to remove without breaking. Additionally, fans have different end connectors. The connectors differ with each model and generation. This means the components cannot be re-used in another type of server. Similar design principle is applied to hard disks and power supplies. While these components may be switched between adjacent generations, using them between different server brands may not be possible.

Further part design inconsistencies are not only present between models and brands, but even between adjacent generations. These are often small changes in chassis design that prevent part reuse. For example, the locking mechanism used for lids is placed in a different location depending on the server generation. Because of this, a lid can only fit its designated machine generation. Yet, this design modification does not enhance the server performance. The same design trend is seen in the design of the chassis and rail assemblies. Typically, component constraint points are moved or redesigned completely to stop parts from being interchanged between generations or models. This creates the necessity to produce a different set of chassis, fan cages, hard disk caddies, power supply units and cooling assemblies for every new model and generation and promotes unnecessarily excessive manufacturing.

One server model usually has two design options for the disk drive bays, as there are two sizes of hard drives: 3.5 and 2.5 inch, or LFF and SFF (large and small form factor) respectively. There are either the chassis designed to fit LFF disks, or the chassis is designed to fit SFF disks.

Finally, the use of plastics and other materials to enhance the aesthetics of the design and to distinguish between the products is very common. However, the continuous improvement of the aesthetics is not necessary as servers are designed for performance and function. These machines are placed in racks concealed inside datacentres with only technical staff to look at them.

Although the above design alterations do not affect the performance of the servers, new components are made every time a new server upgrade is released. Such design approach needs addressing as this does not align with the CE narrative.

DISCUSSION: BROADER CONSIDERATIONS

- Commercial opportunity has frequently been the catalyst for successful circular economy examples; whether driven by the need for resource security or to create value-add in a low margin market – “servitisation” is a classic example, where many providers have moved from a sales model to a leasing model. Servers-as-a-Service is already emerging as a business model.

- A robust business case, or at least certainty regarding costs, is a critical enabler.

- With respect to digital devices, circular economy practices are more readily applicable to the business-to-business market and are harder to apply successfully in the business-to-consumer market. A robust business case is critical here.

- While much has been done by European regulators to develop a holistic and coherent approach to the circular economy, there is still plenty of opportunity for European policy makers to deliver an improvement in regulatory coherence

- Finally, the circular economy should not become a sacred cow - an ideology in its own right: policy objectives should focus on the positive environmental and economic outcomes that a circular economy delivers, rather than on the circular economy concept itself. We need to recognise that there is a gap between policies that “look circular” and policies that encourage circular innovation without restricting it.

FURTHER INFORMATION AND REFERENCES

CEDaCI Project

Website: https://www.cedaci.org

Circular Economy and CRM

- CEDaCI Situational Analysis Report: https://www.weloop.org/wp-content/uploads/2021/09/2020_04_16_CEDaCI_situation_analysis_circular_economy_report_VF.pdf
- Critical Raw Materials: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474

LCA and Server Refresh:

- The life cycle assessment of a UK data centre: Dr Beth Whitehead, International Journal of Life Cycle Assessment, 2015: https://link.springer.com/article/10.1007/s11367-014-0838-7
- A Comprehensive Reasoning Framework for Hardware Refresh in Data Centres, Dr Rabih Bashroush, Published by IEEE: see: https://ieeexplore.ieee.org/document/8263130#full-text-header

Data Centre Standards:

- Green Data Centre Brochure (summary): CENELEC https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN%20sectors/Digital%20Society/Green%20Data%20Centres/brochuredatacentrestandardizationedition8_2021.pdf
- Data Centre Standards, Detailed document: CENELEC: https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN%20sectors/Digital%20Society/Green%20Data%20Centres/standardizationlandscapegdc_edition8_2021.pdf

Policy and Compliance

- European Commission Study on Energy Efficient Cloud Computing and Policies for an Eco-Friendly Cloud Market: Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market | Shaping Europe's digital future (europa.eu)
- Data Centre Compliance Checklist: techUK, 2020: https://www.techuk.org/asset/DA768B84-B459-4954-ABC2AE068266A4E4/

Industry Initiatives

- Climate Neutral Data Centre Pact: https://www.climateneutraldatacentre.net/
- Infrastructure Masons: https://imasons.org/

Energy and Carbon

- EURECA Project Report and Results: https://cordis.europa.eu/project/id/649972/results

- Energy Tracking Report on Data Centres and Data Transmission Networks, International Energy Agency (IEA) 2020: https://www.iea.org/reports/data-centres-and-data-transmission-networks

- Data Centre Energy Analysis: Past, Present and Future Explanatory video by Eric Masanet, Professor and Mellichamp Chair in Sustainability Science for Emerging Technologies, UC Santa Barbara, 2021. https://www.youtube.com/watch?v=-o8j5zIM0iA

- Data Centre Energy Use: the Viking Helmet, 2021: https://www.techuk.org/asset/A3AB67E8-C581-4AC6-B986C4B80B3B2C95/

- Electricity Intensity of Internet Data Transmission: Untangling the Estimates: Aslan, Mayers, Koomey and France; Journal of Industrial Ecology 2018: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3226029

- Does Not Compute: Avoiding Pitfalls Assessing the Internet's Carbon and Energy Impacts: Jon G Koomey and Eric Masanet, 2021: https://www.gwern.net/docs/cs/2021-koomey.pdf

- The Internet is Not Run by Magic: FAQ: https://www.techuk.org/asset/E9947938-9B56-49C4-9D72773BE7EE177E/

- Data Centre Sector Energy Routemap, techUK 2019: https://www.techuk.org/asset/5A758AB3-990C-4733-8C8B26512A6F229B/

- Lost in Migration: Attributing Carbon to Cloud, techUK 2019: https://www.techuk.org/asset/93FF77C6-6198-432C-B9EE86928B107571/

Endnotes

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[i] **CEDaCI Project situational Analysis report:** https://www.weloop.org/wp-content/uploads/2021/09/2020_04_16_CEDaCI_situation_analysis_circular_economy_report_VF.pdf

[ii] Back in 2015 the Ellen MacArthur Foundation published *Growth Within: A circular economy vision for a competitive Europe and* estimated that by adopting circular economy principles, Europe can take advantage of the impending technology revolution to create a net benefit of €1.8 trillion by 2030, or €0.9 trillion more than in the current linear development path. This would be accompanied by better societal outcomes including an increase of €3,000 in household income, a reduction in the cost of time lost to congestion by 16%, and a halving of carbon dioxide emissions compared with current levels. Previous calculations by the Ellen MacArthur Foundation has estimated this opportunity as US$1trillion per annum in cost savings globally by 2025 and in Europe at US$380bn in savings during the transition and US$630 billion with full adoption; See Towards the Circular Economy reports 2 and 3.

[iii] **What is a data centre?** A data centre is a building (or self-contained unit) used to house computing equipment such as servers along with associated components such as telecommunications, network and storage systems. A data centre is equipped with a guaranteed power supply and high bandwidth connectivity. Resilience is critical so redundancy (duplication) of networks, power and other infrastructure is common to ensure continuity. Building management controls such as air conditioning maintain the environmental conditions for the equipment within a specified envelope of temperature and humidity, and security systems ensure that the facility and its data remain secure.

[iv] **What is digital infrastructure?** Our core digital infrastructure is not a single system but multiple systems and networks that interoperate. The three main constituents are fixed line telecommunications (made up of the high capacity and highly resilient core network plus the access network that runs from the exchanges to tens of millions of individual customer premises), mobile telecommunications (that interact with the core network but provide customer coverage through a cellular network) and data centres (that manage, transmit, process and store data for government, businesses, individuals and academia).

[v] **See: The Data Economy Report, Digital Realty 2018**:
https://digitalrealty.box.com/s/bserfy44rne36jxupnnnirdcbwdcvp7f

[vi] **See International Energy Agency:** https://www.iea.org/reports/data-centres-and-data-transmission-networks

[vii] See **Data Centre Energy Use: The Viking Helmet**, techUK 2021, which debunks this and other myths:
https://www.techuk.org/asset/A3AB67E8-C581-4AC6-B986C4B80B3B2C95/

[viii] See: https://cordis.europa.eu/project/id/649972/results

[ix] **PUE** means Power Use Effectiveness and is the ratio of total power delivered to the facility to the power consumed by the IT within it. A high PUE is therefore undesirable, as it indicates a high energy overhead and low facility efficiency. PUE cannot go below 1 but the closer to 1 a facility can get, the more efficient it is considered to be. PUE is not a perfect metric: it is frequently and incorrectly used as a metric for overall data centre energy efficiency. PUE does not indicate overall data centres energy efficiency as it excludes the efficiency of the ICT that it houses. It is a useful trend analysis tool.

[x] https://cordis.europa.eu/project/id/649972/results

[xi] See: Study on Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market

[xii] See: **EURECA Project Report and Results:** https://cordis.europa.eu/project/id/649972/results

[xiii] See **Data Centre Performance Metrics for Tiny Tots**, 2017 https://www.techuk.org/asset/85C8F33F-5A22-45B6-B202D363A2399ED3/ and techUK Standards Map 2017 https://www.techuk.org/asset/21785EFD-F437-4A23-A691AFB2E0694F62/ but be aware that much has changed since publication and these are due an update. New standards have emerged and many metrics are now formally standardised.

[xiv] See https://www.climateneutraldatacentre.net/