**Chapter 11**

**Sustainable Development Goals, Circularity and the Data Centre Industry: a review of real-world challenges in a rapidly expanding sector.**

Dominika Ptacha\*, Deborah Andrewsa and Simon P. Philbina.

a London South Bank University, School of Engineering, 103 Borough Road, London, SE1 0AA, UK

\*Corresponding email address: ptachd2@lsbu.ac.uk

ABSTRACT

The last three decades have seen rapid growth in the data centre industry (DCI), which has significantly affected the world we live in today. With the supposedly positive impact of digital technologies, nobody questioned the sustainability of the industry for many years. Only recently, research has started to identify the trade-offs of the information and communication technology (ICT), particularly for data centres (DCs). The increasing environmental concerns sparked discussions about sustainability in many industries, governments, and communities, including the data centre industry. Although the relationship between business and the goal of pursuing sustainability remains complicated and has not been fully explored through research, various studies have emphasised the need to move beyond business as usual. Therefore, businesses within the DCI need to contribute to achieving the SDGs and offset the significant impacts of this sector on the environment, including resource depletion, critical raw materials extraction, unethical labour practices and more. This chapter presents an overview of this unique sector in the context of the impacts across three pillars of sustainability and circular economy-inspired initiatives. Furthermore, it reviews opportunities for the sector to contribute to sustainable development goals and presents research gaps in present awareness and approach to tackling the SDGs.

1. **Introduction**
2. Significance of the Data Centre Industry.

Data centres play a crucial role in today's global society and digital economy. Whether we are searching for news on our smartphones or connecting to a virtual meeting at work, data centres are in the background of all online activities. Organisations across various sectors that process, store, and disseminate extensive amounts of data rely heavily on data centres. Indeed, the world had already recognised their growing importance since the COVID-19 pandemic when many services moved to online provision and the volume of internet users increased remarkably. Although it appears to be problematic to grasp the true impact of digital infrastructure as the term "cloud" seems intangible. However, data centres are the engines of all digital products and services, and an estimated 7.2 million data centres with 70 million servers are continuously running to provide digital services across the globe1. The energy-intensive operations and infrastructure embodied footprint of the Data Centre Industry (DCI) substantially impact the economy, society, and environment. On that account, data centres, as the backbone of all information and communication technology, significantly impact several of the United Nations (UN) Sustainable Development Goals (SDGs), for instance: Goal 7: Affordable and clean energy; Goal 9: Industry, innovation, and infrastructure; Goal 11: Sustainable cities and communities; Goal 12. Ensure sustainable consumption and production patterns; and Goal 13: Climate action.

The DCI is one of the fastest-growing sectors. According to the report by DataReportal titled "Digital 2022 Global Overview" 2, the world's population stood at 7.91 billion in January 2022, with 4.95 billion internet users representing 62.5% of the world's total population. Furthermore, due to ever-growing digital adoption, internet users have doubled in the last decade, global internet traffic grew 15-fold between 2010 and 2020, and a further 40% growth occurred in 2020. Data processing and producing data is the primary driver of the industry. The last decade has seen 550% growth in data centre computing operations3, and predictions state a further fivefold increase in global demand and reliance on data centres by 20304. This trend is driven by the growing popularity of services and technologies, such as video streaming, bitcoin mining, and the internet of things (IoT).

Some sources claim that approximately 7.2 million data centres are working 24/7 worldwide to meet the constant and growing demand1,5. Different sources report various levels of activity in the sector. Moreover, Intellect UK6 explains that the total number of data centres remains unknown due to inconsistent definitions of what a data centre is. Most data centres are congregated in four main countries across the world, namely the United States, Germany, the United Kingdom, and China. More than half of Europe's data centres are concentrated in the North-West of the continent, with the highest number - 456 data centres in the UK7,8.

1. About Data Centres

Data centres originated from large computer rooms that were first built in the 1940s. Later in the 1980s, the introduction of microcomputers allowed the transfer of networking equipment to designated rooms, naming those spaces "data centres" for the first time. The industry experienced tremendous growth on the verge of the new millennium. Due to the "dot-com bubble" and the rising number of Internet users, companies started to build Internet Data Centres (IDCs) rapidly. Since then, data centres have generally remained the same except for consecutive technological advances.

Data centres are the physical facilities housing the computer systems and supporting equipment. The Green Grid describes data centres as:

*"a building or portion of a building whose primary function is to house a computer room and its support areas. Data centres typically contain high-end servers and storage products with mission-critical functions."*

Depending on the definition, data centres can vary from small cabinets through to designated rooms or entire floors to a complex of large warehouses - the largest data centre campus in China takes up to one million square metres9. Intellect UK6 reports that infrastructure qualifies as a data centre if operated with specific environmental and safety controls; therefore, a standalone rack of servers does not qualify as a data centre. Furthermore, data centres comprise the following components: a facility, computing infrastructure (including servers, storage and networking equipment, firewalls, cabling, and racks), support infrastructure (such as uninterruptable power supply, heating, ventilation, and cooling (HVAC), and security) and operational staff10.

1. Data Centre Business Models and Subsectors

There are various types of data centres, which organisations choose to engage with according to their requirements. The main types of the data centre include:10

* **enterprise** (in-house data centre managed within the organisation),
* **cloud** (providers leasing infrastructure as a service),
* **colocation** (rental spaces in a data centre, where organisations can install their own hardware, but the infrastructure is provided)
* **edge** (small data centres at a required location),
* **hyperscale** (large-scale providers such as Amazon, Google, and Meta)

There are two primary business models, namely: wholesale and colocation. In the first model, multiple customers store servers in rented racks in a shared facility, and in the second model, one customer rents a third-party facility exclusively11.

The data centre industry is extensive and involves various actors and 11 sub-sectors, as consolidated by the Circular Economy for the Data Centre Industry (CEDaCI) project12 (See Figure X.1). The stakeholders include:

* Suppliers (this includes suppliers of rack and cabling or energy)
* Designers and manufacturers of computing hardware and ICT infrastructure
* Building construction and maintenance companies
* Data centre operations
* Decommissioning and data sanitation services
* Recyclers, refurbishment services and re-manufacturers

[Figure X.1 near here]

1. Data Centre Industry Impacts Across the Triple Bottom Line

The structure of this section follows the three dimensions of sustainability as defined by the triple bottom line definition13 and explained in Chapter 2. Examples of positive and negative impacts are presented subsequently across the pillars of the economy, environment, and society. The environmental impacts are further divided into subsections concerning energy consumption, renewable energy, greenhouse gas emissions, water consumption, and resource consumption.

1. Economic Impacts

Data centres are the backbone of the digital economy, which researchers, governments and businesses recognise as key to economic growth. The statistics are evidence of the economic significance of data centres globally. For instance, the data centre sector contributes over 5% of gross value added 14 (value generated by any unit engaged in the production of goods and services). Moreover, the UN Conference on Trade and Development in Digital Economy Report in 2019 estimated that the digital economy size ranges from 4.5% to 15.5% of GDP (gross domestic product), depending on the scope of the definition15. According to Cloud Scene8, the market for data centre providers in the UK is thriving, and the digital economy contributes 8% to the total GDP. The market for UK data centres is the second largest in the world and the largest in Europe, with a vital cluster in London. As identified by the Tech UK16 report, "*Each new data centre contributes between £397M and £436M gross value added per year to the UK economy while that of each existing data centre is estimated to lie between £291M and £320M per annum*". The data centre sector, therefore, is and will remain of great attention and value to local and global economies.

Data centres are essential to the public because of the services they deliver and the employment they also provide. According to Uptime Institute17 statistics, the data centre sector employs many highly skilled professionals - approximately 2 million full-time employees worldwide in 2019. Moreover, the resourcing requirement is projected to rise to 2.3 million people by 2025. The highest employee demand is likely to come from colocation, cloud, and consumer internet companies, especially in the developing markets of the Asia-Pacific (APAC) region but less in North America and Europe, the Middle East and Africa (EMEA). More mature markets in the US and western Europe will create opportunities for senior specialists. Often located in sites away from the cities, data centres offer valuable and well-paid career opportunities for the local communities. Although, others argue that data centres create few job openings due to innovations in automation, such as using artificial intelligence (AI) monitoring technologies. Some automated data centres have been built in the arctic circle, where no staff are required, for instance, the Facebook data centre in Lulea, Sweden. However, Uptime Institute17 predicts that the automation and use of AI are believed to have an insignificant impact on staffing demand.

The above trends significantly impact the economy and wider society, thereby creating educational paths and career opportunities. The DCI workforce requires relevant further or higher education as well as role-specific training. Therefore, the industry also offers many apprenticeship prospects. As Intellect UK outlines in the report titled "So what have data centres ever done for us?"14, the DCI sector involves various technical and additional roles. Furthermore, direct, and indirect jobs can be differentiated to help understand the employment landscape. Direct employment comprises roles in the design and construction of the facility and management of data centre infrastructure. Indirect employment is much broader and involves people employed in supply chains and those in colocation services. Some examples of indirect roles, which demonstrate a wide range of careers in the sector, include the following:

* Location consultants and location finders
* Planning consultants and planning advocacy services
* Real estate companies who sell data centre capacity and negotiate deals
* Data centre search and selection companies
* Lawyers and contract negotiators
* Specialist accountants, finance consultants and providers
* Energy managers and energy consultants
* PR and media consultants
* Industry associations, professional bodies, and standards bodies
* Conference organisers and specialist publishers

1. Environmental Impacts

Energy consumption and associated GHG (greenhouse gas) emissions are receiving significant attention in the data centre sector, which is primarily due to the recently introduced decarbonisation policies as part of the Paris Agreement Under the United Nations Framework Convention on Climate Change, also calledtheParis Agreement. There is limited data available on GHG emissions of the DCI sector. However, the International Energy Agency18 (IEA) reported that data centres and transmissions network produced approximately 300 Mt CO2-eq in 2020 (including embodied emissions). Although the GHG emissions from data centres and network operations are significant, it is vital to underline the non-energy impacts of the sector. The sector needs to recognise environmental impacts associated with resource pressures of hardware and infrastructure manufacturing (such as raw materials extraction, including critical raw materials and rare earth elements), water and energy consumption during operations and associated e-waste and end-of-life scenarios. Environmental and social impacts need more attention and action from industry, governments, and researchers. Scoping and measuring both emissions and broader environmental impacts is complex, but assessment is crucial to understand the true level of sustainability, reduce footprints and reach climate agreements.

Researchers 19–22 agree that a life cycle approach is necessary to assess the sustainability impacts of the DCI fully. The *Life Cycle Assessment (LCA)*method is systematised by the ISO 14044 standard and further adopted by the Green Grid23, specifically for the data centre sector. It considers all life cycle stages, from materials extraction and manufacturing of IT hardware and construction of a building, through to operations, decommissioning and end-of-life scenarios, thereby uncovering both embodied and operational environmental impacts. Although the level of sophistication and the large number of data centre components often make LCA assessment problematic and time-consuming. Furthermore, there is a need for open-source, primary inventory data to conduct accurate assessments. There are a small number of research studies on the life cycle assessment of data centres, including studies by Letteri24, Shah25 and Whitehead21,26. All these studies identified that operations are directly responsible for environmental impacts. However, the embodied carbon impact cannot be overlooked, and the significance of embodied impacts will likely increase according to sectoral growth and improved operational energy efficiency.

Other evidence of possible non-energy impacts of digitalisation on the environment was presented in the report by Öko Institute, titled "Impacts of the digital transformation on the environment and sustainability" 27 for the European Commission. As in other LCA studies, the authors pointed out that there are broader implications beyond GHG emissions and the high energy consumption of data centres. In this regard, they collected literature on resource depletion, water consumption, land use and land use change and biodiversity and presented a comprehensive review of broad systemic impacts.

1. Energy Consumption

The data centre industry is promoted as a high-energy consumer. However, industry practitioners argue that the sector is not the most significant offender when looking at the numbers and trends and instead point at the user demand and energy-intensive technologies, such as blockchain (a system in which a record of transactions made in bitcoin or another cryptocurrency are maintained across several computers that are linked in a peer-to-peer network). The electricity use of a data centre was first researched by Koomey28 in 2008 and followed by many other researchers3,29,30. According to Greenpeace31, 21% of electricity consumption in the IT sector was used by data centres, 29% by networks, 16% by manufacturing and 34% by electronic devices. The most recent data from the IEA18 reveals that data centres used between 220 and 320 terawatt hours (TWh) of energy in 2021. This is 10-60% more than in 2015, when the approximate usage accounted for 200 TWh. The energy utilised by data centres is equivalent to that of some nations, for instance, the United Kingdom (294.4 TWh in 2021). In 2021 data centres accounted for 0.9-1.3% of global electricity demand. These numbers exclude the data centre transmission networks, which consumed additional 220 TWh in 2015 and 260-340 TWh.

The increase in energy consumption in the last decade is limited due to the energy efficiency improvements in hardware and cooling. Another reason is clustering and integrating smaller, ineffective data centres into the bigger and more efficient facilities, which counterbalance the rise in energy consumption. Nevertheless, data centres need to be wary of *the energy efficiency rebound effect*as the savings from the above practices are constantly challenged by the ever-rising demand for digital services. Still, some forthcoming energy demand models are controversial and troubling. A projection created by Andrae32 in 2015 assumed an increase in electricity consumption by a factor of 3-8% a year between 2019 and 2030.

1. GHG Emissions

Eurostat33 defines *greenhouse gases* as a group of gases contributing to global warming and climate change. The Kyoto Protocol (1997) defines the seven gases, including carbon dioxide, methane, nitrous oxide and four fluorinated gases. For ease of measuring and comparison, GHG are measured in carbon dioxide equivalents (CO2). Hence carbon is often the centre of focus, and another term used interchangeably with GHG emissions is carbon footprint.

For 2020, IEA18 reported an estimated 300 million tons of CO2 embodied and operational emissions for data centres and transmission networks combined, approximately 0.6% of global emissions. For reference, this number is higher than the total CO2 emissions of Poland in 2021. That is 16% higher than the anticipated emissions calculated by the Climate Group (GeSI) in 2008, which estimated the total carbon footprint to reach 259MtCO2 in 2020. Another source, Climatiq, calculated that global emissions from cloud data centres range from 2.5% to 3.7% of all global greenhouse gas emissions. Therefore, we can ask the following question: What do these carbon emission numbers actually mean to the data centre industry?

The GHG Protocol Corporate Standard34 describes a multi-level international accounting tool in which GHG emissions are categorised into three groups or 'scopes'. Scope 1 includes direct emissions from owned or controlled sources, for example, running vehicles. Scope 2 includes indirect emissions from the generation of purchased electricity. Scope 3 includes all other indirect emissions from both upstream and downstream of the company value chain. Indeed, it is particularly challenging to assess the GHG emissions for data centre services due to the complexity of the infrastructure and the often shared services. GHG Protocol has therefore prepared comprehensive guidance for ICT businesses which follows a life cycle approach. The framework35 considers three components for data centre services, namely: emissions of the data centre, the network, and the end-user devices. Although accounting for the energy of the connected devices may escalate the numbers dramatically. For instance, the Carbon Table 2. In Microsoft Sustainability Report 202136 (page 18) shows nearly 124,000 and 164,000 metric tons of CO2 for Scope 1 and 2, respectively. At the same time, Scope 3 emissions reached 13,785,000 metric tons of CO2. Scope 3 outweighed Scope 1 and 2 nearly 48 times, regardless of the savings made in direct and indirect emissions. This example demonstrates the significance of supply chain emissions, which is the most carbon-intensive segment, but is often ignored, misunderstood and unreported, accounting for up to 80% of total company impacts. GHG Protocol emphasises that focusing on GHG emissions is a good point of reference for businesses to assess their environmental performance, and Scopes 1 and 2 are good places to start due to data availability. Meanwhile, Uptime Institute Data Centre Survey37 from 2022 reports that only 37% of companies collect carbon footprint data, thereby indicating a substantial opportunity for improvement.

1. Renewable Energy

It can be observed that all the energy consumed by the sector would lead to enormous GHG emissions if the electricity were produced only by combusting fossil fuels. This is because burning oil, gas, and coal leads to increased carbon in the atmosphere, which in a broader context, causes climate change and has a negative impact on the environment overall and human health. Consequently, under pressure from the media, legislators and clients, the data centre sector heavily invests in renewable energy to improve its reputation and environmental profile and avoid price volatility. Hyperscale cloud operators have the advantage in renewable energy procurement. Due to the nature of the cloud business model, such operators control their direct energy procurement and locate sites close to renewable resources. Hence hyperscalers are the primary purchasers of all corporate power purchase agreements (PPAs), with Amazon Web Services, Microsoft, Meta, and Google are leading the way in this area 18,38.

There are different sustainable strategies for procuring renewable energy. The most common are *renewable energy certificates* (RECs) and *power purchase agreements* (PPAs). RECs are defined as: *“a market-based instrument that certifies the bearer owns one megawatt-hour (MWh) of electricity generated from a renewable energy resource”*39.  However, this approach does not guarantee that the energy used is “green”. For instance, the energy mix in the region of data centre operations may be fully supplied by fossil fuels, and the purchased renewable energy will be generated and used elsewhere. PPAs are contracts between suppliers and buyers to purchase energy at a specific cost, volume, and timeframe. There are two types of PPAs, which are direct/physical or financial/virtual. Only the first type allows for the physical delivery of renewables to the buyer, and the second type sells the power to the wholesale market40.

The aforementioned strategies can be regarded as offsetting mechanisms, which aim to alleviate previously generated emissions. However, those offsets do not reduce or remove emissions completely. PPAs and RECs still face problems in matching renewable energy purchased and the energy consumed by the facility. Moreover, they are often used to greenwash companies' sustainability portfolios40. Nevertheless, these procurement strategies enable renewable energy investments globally and help to decarbonise the energy systems.

1. Water Consumption

Water scarcity is becoming a global problem, and the data centre industry also contributes to water stress and competition for water sources with local communities. Some controversial projects and recent environmental disasters have brought more attention to the water issue. For instance, Google's Luxembourg data centre proposal in 201941 or recent news headlines questioning data centres' water use during the extreme drought in August 2022 in the UK42.

Data centres use water directly for cooling and indirectly through electricity generation (thermoelectric power). Limited studies are available on direct and indirect water use; examples include the work of Mytton43 and Ristic44. The total amount of sectoral water consumption remains uncertain due to the lack of data. Nevertheless, the researchers above were able to present water use estimations. Mytton calculated that US data centres consume 1.7 billion litres of water daily. Therefore, the US DC yearly water footprint stands at 620.5 billion litres. This number is very close to the 2014 average of 626 billion litres reported by Shehabi29, who created a direct and indirect water use forecast for 2014 to 2020. Though the forecast did not oversee the industry improvements in technologies and strategies, in fact, electricity generation is responsible for most of the water consumed. Furthermore, Rustic documented that data centres use between 4 and 544 Litre of water per kWh, and outbound data traffic cause 1 to 205 litres of water per gigabyte. Öko-Institut report27 used these numbers to estimate the total water consumption for a 198ThW data centre in 2018 to be 740 – 106,822 million m3 annually. The range of calculations reflects the uncertainty in the exact number of data centres and the lack of data about water usage according to different variables. Moreover, water footprint studies have tended to explore the operations only. Nevertheless, examining a data centre's whole life cycle, hardware and building manufacturing, decommissioning, and end-of-life scenarios needs to be considered. Moreover, Rustic emphasises the urgent need for more research regarding*“the water intensity of different HVAC technologies in different climates and the water intensity of electricity generation”*and recommends a systemic approach and implementation of standardised metrics. All the above studies suggest that water use in the data centre sector requires the necessary attention and transparent reporting, and further study of the sustainability impacts of water use is also needed.

Another area that requires more attention is alternative cooling methods and the free water cooling or waterside cooling. Some projects using water from natural reservoirs have been implemented thus far, for example, Google's 2011 data centre in Hamina, Finland45. This facility is located near the Baltic Sea gulf, which supplies the data centre with seawater delivered through the granite tunnels built initially for a local paper mill. Cold sea water enters the system and takes the heat away from the site, and before releasing it back into the sea, warm and cold water is mixed to reduce the temperature, so it is similar to inlet seawater. This practice claims to reduce marine life impacts, but data nor independent studies that analyse the long-term effects of such actions are available. IEEE Spectrum46 reports that Microsoft's experiment with submerging a data centre under the sea proclaims no negative results on marine life, as *“any heat generated by a Natick pod would rapidly be mixed with cool water and carried away by the currents. The water just meters downstream of a Natick vessel would get a few thousandths of a degree warmer at most.”*Nevertheless, scientists warn that ocean thermal pollution can adversely affect aquatic life, causing oxygen level reductions, disruption to animal reproductive cycles, and other physiological impacts47. Moreover, there is no legal control over utilising the ambient environment as coolants, which puts a question forward whether using seawater for cooling is truly environmentally friendly and green, as companies claim.

1. Physical Resource Consumption

A significant majority of concern focuses on climate change and the environmental impacts of data centre operations (i.e., energy-related), the embodied impacts of a data centre and those at the end of life are often overlooked20. While manufacturing uses more than a quarter of electricity in the IT sector, electronic and electrical equipment cause 1 to 4% of environmental impacts in Europe alone48. Each piece of data centre hardware contains more than 50 materials: ferrous and non-ferrous metals, platinum group metals (PGM), precious metals (PM), rare earth elements (REE), plastics and, in some cases, ceramics12. Twenty-three of 30 elements used in IT hardware European Commission are classified as Critical Raw Materials (CRMs)49,  which can be considered as strategically significant resources for the growth of the European economy at high risk of limitations and disruptions to their supply chains. Raw materials are not finite; therefore, endless extraction and wasteful linear consumption threaten resource availability for future generations. Moreover, researchers have identified environmental impacts associated with material extraction and mining waste from linear consumption, including land use change and air, water and soil pollution with heavy metals and radioactive particles. For instance, the largest cobalt and tantalum deposits are concentrated in the Democratic Republic of Congo (DR Congo), a politically unstable region associated with unethical artisanal mining, where extraction causes land degradation and soil pollution and threatens the agriculture sector50.

Researchers4,22 emphasise the urgent need for higher material resource efficiency in data centre equipment to secure the future supply chain of critical materials. Furthermore, CEDaCI research identified printed circuit boards (PCBs) as components with the highest environmental impact, advising recycling and refurbishment take-back schemes for economic value preservation and environmental impact reduction. The research also advocates responsible data centre equipment consumption and eco-design improvements to accommodate more efficient material recovery. Such practices and new business models, particularly the circular economy, need to be promoted in the data centre sector since most efforts concentrate on energy consumption only. The circular economy is a key to the long-term benefits across all three pillars of sustainability and therefore ensures a safe and prosperous future for many industries.

1. Social Impacts

The data centre industry, and specifically the digital infrastructure, strongly influences the local and global economy and environment, and has numerous associated societal and political implications. Some reported spillover effects include unethical labour practices, gender inequalities, hazardous working conditions, water scarcity and pollution27. These potential systemic impacts are not direct effects of the industry operations and are primarily associated with the highly complex and long supply chains of electronics and electrical equipment. Nevertheless, there are also positive contributions of the industry to the digitalisation of developing countries, such as providing access to the internet and education for many remote areas in low-income countries. The sector needs mechanisms to pinpoint and address systemic social impacts and often overlooks this pillar of sustainability, which is paramount to the holistic perspective.

As a result of numerous corporate scandals in the 1990s, growing distrust in business activities, and rising public environmental awareness and concern, companies were pressured to act transparently and ethically. Ever since, businesses carefully monitor activities to maintain their reputation, as associations with unethical practices can put the company image to customer boycotts and damaging financial costs. Subsequently, a notion of Corporate Social Responsibility (CSR) was developed, and in 2008 the International Organisation for Standardisation (ISO) formulated voluntary, universal guidance (ISO 260000) for implementing it in business practice. CSR assumes organisations' responsibility for its decisions' environmental and social impacts and advocates for transparency and ethical conduct. ISO 260000 is strongly encouraged in business practice, yet it is still voluntary in many countries. In European Union, CSR reporting is outlined by Directive 2014/95/EU, commonly referred to as the Non-Financial Reporting Directive (NFRD). The directive covers non-financial information disclosure on subjects concerning the environment, social conduct towards employees, human rights, anti-corruption and bribery and diversity of the company board. It is soon to be replaced by a broader scope covering all businesses regardless of size, the Corporate Sustainability Reporting Directive (CSRD). Concerning the UK, CSR is encouraged but not mandatory.

As mentioned previously, CSR coverage limits social sustainability to the borders of direct influence, such as immediate employees and headquarters. Furthermore, social sustainability can be interpreted in many ways, and it is hard to formulate a single definition51. Nonetheless, an understanding of indirect implications in a systemic context of business actions is needed.

One of the assessment methodologies currently recommended by UNEP is developed by the Social Life Cycle Initiative social life cycle assessment (s-LCA)52. The method is used for assessing the social and socio-economic impacts as well as the potential impacts of products and services. This method analyses good and adverse implications from extraction and processing of raw materials, manufacturing, logistics, operations, reuse, maintenance, recycling, and landfill disposal – i.e., a whole life-cycle perspective. S-LCA is becoming of increasing interest to businesses, thereby allowing for transparency and mapping hotspots for improvement and overall sustainability, which is not only becoming an essential requirement for clients, but also an opportunity for unlocking new potential for businesses.

The most significant issue with s-LCA is the need for more open-source data. Compared to the popularity of the life cycle / environmental impact assessment has become (the most extensive database, Ecoinvent has more than 18,000 datasets), s-LCA databases only account for 1,000 to 5,000 publicly available studies. Currently, limited or no known literature sources explicitly discuss the data centres' social impact. However, the social effects can be explored by looking at electronic and electrical equipment as well as data centre buildings, specifically materials used for manufacturing those mentioned earlier and the end-of-life scenarios. There are numerous resources exploring social and political issues associated with materials extraction and e-waste, for instance, Global E-Waste Monitor53 or Ellen MacArthur Foundation e-waste reports54.

Data centre equipment has a significant embodied impact; Whitehead26 estimated that during the assumed 60-year-long life of a data centre, 15% of its impact derives from the building and facilities, while the remaining 85% derives from IT equipment. Two primary materials of data centre building are concrete and steel, while manufacturing digital infrastructure equipment requires three primary materials: "common" metals and polymers and critical raw materials (CRMs). This includes various metals such as steel, copper, aluminium, zinc, and brass; polymers (such as ABS, HDPE, PUR, PVC, GPPS, PBT, and EVA); and CRMs including antimony, beryllium, chromium, cobalt, lithium, magnesium, palladium, silicon, dysprosium, neodymium, praseodymium and terbium. Although the CRMs account for 0.2% of the equipment, Andrews4 argues they are crucial to the electronics' functioning and, therefore, of high economic value. Moreover, some elements - gold and 3T: tantalum, tin, and tungsten - are classified as Conflict Minerals (CMs), that is, minerals extracted in politically unstable regions. Mines of these conflict resources are located in African countries, particularly the eastern, remote regions of the Democratic Republic of Congo controlled by armed rebel groups. Consequently, extracting these precious elements results in local conflicts and even war and cruel exploitation of local communities, including children and women. The 2018 study by UN Environment Programme55 estimated that around 15 million people work in the artisanal and small-scale gold mining (ASGM) sector globally, including over 600,000 child and 4.5 million female workers. For many local communities, however it is the only opportunity for income and livelihood guarantee.

The data centre industry is one of the sectors contributing to the Waste Electrical & Electronic Equipment (WEEE) and contributes to growing regional and global e-waste streams, reached 54 million tonnes per year in 202053. Approximately 83% of e-waste end-of-life management is undocumented, and often the end-of-life of WEEE remains unknown. Possible scenarios include dumping, burning, trading, or recycling in illegal or uncompliant conditions. The remaining 17.4% of recorded e-waste is still likely to be mishandled by either ending up in a landfill or exported to low-to-middle-income countries to avoid recycling costs. For instance, Nigeria and China both struggle with the infamous illegal e-waste industry, which has a damaging impact on local communities and the environment and is the primary hotspot for illegal workers. It is impossible to pinpoint a specific number of people employed in the entire illegal e-waste industry. However, World Economic Forum report53 speculates that in Nigeria, the number of workers stands at approximately 100,000, while in China, the number possibly reaches 690,000. Together it accounts for more than the population of Leeds in the UK. Moreover, the ratio of female and child workers in Africa and Asia working in e-waste processing plants accounts for 30% of the workers. People engaged in uncontrolled and illegal recycling or disposal activities often lack protective equipment, suitable tools and safe working conditions and unknowingly mishandle toxic substances. Some processing techniques include burning or melting the electronic parts in acid to collect valuable metals. The results of such practices and exposure to many highly toxic fumes and substances can have long-lasting effects on human health and well-being. Some of the atrocious effects include carcinogenic diseases caused by exposure to heavy metals and radioactive uranium. Other consequences affect specifically women's sexual and prenatal health, causing miscarriages and premature and stillbirths. Also, new-born babies are at risk of low birth weights, defects, and high infant mortality. Furthermore, in the even broader context, non-direct impacts of mishandling e-waste include water, air and soil pollution, contaminant food chains and drinking water, which can have a catastrophic impact on human health.

On the contrary, digital infrastructure plays an important role in providing services to the developing countries of the Global South. The digital divide between developed and developing countries significantly impacts **many**people. Furthermore, the COVID-19 pandemic has even further increased the inequalities in access to digital services.  Connectivity is mostly provided thanks to mobile networks and the underpinning network towers. Interestingly, rapidly developing African countries are becoming attractive regions for new data centre projects. Currently, there are 86 colocation data centres from 15 countries in Africa56.

1. Current State Opportunities for the DC Sector to Support the 2030 Agenda

This section explores sustainability in the context of business and outlines the reasons why the private sector, specifically the data centre industry, should support sustainable transformation and the pursuit of a trajectory towards realising the UN SDGs. It also discusses the sustainability maturity of the sector and reviews standards and initiatives in the sector as well as current reporting requirements. Finally, the section presents the findings on reported metrics and SDGs from recent sustainability reports and other documents, such as CSR or ESG reports, which are available in the public domain.

1. Business vs Sustainability

Research often portrays business and sustainability as subjects that contradict each other due to conflicting prerogatives. Although the Brundtland Commission developed a standardised definition of sustainability, it is frequently used interchangeably with CSR or ESG definitions. Moreover, the intersection of business and sustainability linkages still needs further exploration in research. The concept of the three sustainability dimensions (i.e., environmental, social, and economic) has been in place for many years now. Still, many industries do not fully understand the holistic approach, as described by Dyllick57, who demonstrates the great divide between business sustainability and sustainable development in their work.

As explained in Chapter 2 of this book, page x, the Triple-Bottom-Line (TBL) concept coined in 1994 was created with businesses in mind, initially as an accounting framework to measure business performance other than financial performance. Furthermore, the Environmental, Social and Governance (ESG) framework was developed for investments, as well as GRI standards, which are widely used by the industrial sector. Nevertheless, with the private sector's immediate attention on financial growth, it is unlikely that Elkington's triple bottom line's social or environmental values will be the leading business concern58,59. For decades, sustainability appeared to be only a Corporate Social Responsibility (CSR) strategy. However, according to Azapagic and Perdan60, companies' performance in environmental and social contexts started to matter to the public in the new millennium. Which is inspiring debates on how the private sector can support sustainable development.

1. The Private Sector – a Key Agent in the 2030 Agenda

The 2030 Agenda for Sustainable Development61, consolidated by the United Nations, outlines the scale, ambitions, and means of implementing the proposed goals and targets. As the recent 2022 progress update suggests, initial progress on the sustainable development goals is insufficient, and it is estimated that the targets will not be achieved in the given timeframe. Moreover, the COVID-19 pandemic has further reversed the progress towards the 2030 Agenda, pushing many people back into poverty. Therefore, researchers and leaders agree that strengthened action and an efficient strategy are required to progress towards sustainable development.

To achieve the 2030 Agenda, the authors call for Global Partnership. Although the concept is proposed on the global level, primarily addressing national and regional governments of all countries, the UN recognises the importance of engaging other agents: the private sector, society, the UN structures, and all other available resources. In the means of implementation section, the authors emphasise the crucial role of business:

"We acknowledge the role of the diverse private sector, ranging from micro-enterprises to cooperatives to multinationals, and that of civil society organisations and philanthropic organisations in the implementation of the new Agenda"61.

Sachs62 and Hák63 also recognised the significance of the private sector in reaching SDGs. With both multinational and small and medium enterprises, private companies can accelerate all areas of sustainable development locally and globally. The private sector is the main constructive of the global economy and directly influences wider society. Therefore, it is necessary to take leadership and responsibility for its operations by introducing measuring and reporting strategies, shaping policies, and collaborating with the stakeholders62.

There are great opportunities for the private sector to advocate and lead sustainable development. However, the main driver behind the emerging transformation must be critical changes in social and economic models and the introduction of sustainable practices59,64. The current way of conducting business, aka business-as-usual (BAU), solely concentrates on the financial benefit and the exploitation of the economic system and resources57. The BAU approach poses a question, as formulated by Scheyvens59:

"Can, for example, a profit-motivated business really make a meaningful contribution to the achievement of the SDGs or are we likely to see 'business-as-usual', which results in greater profits for some, and lost opportunities for many?

1. Potential of the ICT Sector and Data Centre Infrastructure at its Core

Data centres are the backbone of all digital technologies. Furthermore, technology and the digital economy were recognised by the 2030 Agenda as enabling factors in achieving sustainable development globally. Likewise, the joint research of Earth Institute and Erickson65 identified the ICT sector as having a “great potential to accelerate human progress, to bridge the digital divide and to develop knowledge societies, as does scientific and technological innovation across areas as diverse as medicine and energy”. Another report from Huawei66 also presents favourable arguments for the ICT to support the SDGs. Huawei’s researchers conducted benchmarking exercises to showcase that digitally advanced countries reported higher progress towards the SDGs. Therefore, they suggest that innovation and investment in ICT and infrastructure can positively stimulate sustainable development through wealth creation and expanding highly skilled and digitally literate society.

1. What the Data Centre Industry is Currently Doing Towards Sustainability and the SDGs?
2. Sustainability Maturity and Awareness

Sustainability efforts in the data centre industry primarily focus on energy efficiency due to energy-intensive operations, meaning that other non-energy impacts remain overlooked, as explained in section 2 of this chapter. Moreover, the term "sustainability" has become so fashionable and overused that it has lost its true meaning. Due to limited evidence, there is a need for research on sustainability awareness and the sustainability maturity of the sector. The available sources are reports from publishing bodies such as Uptime Institute or research executed by private companies, e.g., SuperMicro.

Recent articles and reports from Uptime Institute37 warn that the sector's awareness is still low, and attitudes toward green strategies differ between the regions. Europeans appear to see sustainability as an opportunity but are critical of the progress made to date, whereas North America and Asia-Pacific countries are more sceptical. The Uptime Institute Global Data Centre Survey 2021 of 400 data centre owners and operators revealed that 38% of respondents genuinely agree that data centre actions towards reducing energy, water and GHG emissions are meaningful. However, 45% still believe these actions are not delivering any change. Moreover, the survey declares that Europeans are critical of the progress, as 35% of operators think environmental advances are effective and call for more regulations for the sector. On the contrary, in North America, 45% of respondents believe current sustainability commitments are successful, while more than half (55%) disagree with this statement. Interestingly, the findings from the previous year revealed a tendency to deny climate change67 and nearly a third of managers in data centres located in North America did not believe that human activity contributes to climate change or did not believe in climate change at all at the time of the survey.

In another report from SuperMicro68, only 28% of industry decision-makers consider environmental issues when selecting data centre technology. The report explains further that the reasons behind such a small percentage are costs-saving (29%), lack of knowledge and resources (27%) and environmental impacts being outside of companies' main concern (14%). Furthermore, the study shows that 58% of companies surveyed already have an environmental policy or considering one at the time of the survey. Moreover, SMEs may lack the capacity to have such a policy due to a less budget to spend on a more comprehensive and meaningful strategy. Large companies are more likely to employ external experts or create sustainability-dedicated departments to do so. One of the additional reasons for it is that sustainability is a nice-to-have and voluntary addition to the company's picture.

1. Data Centre Industry Standards and Initiatives

The 2016 Paris Agreement on climate change was a wake-up call and groundwork for new policies and regulations. Consequently, various initiatives concerning environmental impacts were initiated across governments, businesses, and academia. In the data centre industry, however, evidence shows that a limited number of such proposals exist.

Presently, there are a few data centre sector regulations and certifications69. Those mainly focus on the energy efficiency of the building or data centre components (e.g., HVAC, servers, data storage), are voluntary or mandatory, and vary between countries or regions, which causes a lack of consensus in the industry. The internationally recognised credentials are, for instance:

* Eco-label EPEAT (Electronic Product Environmental Assessment Tool) for servers NSF/ANSI 426–2019.
* Certification scheme by CEEDA (Certified Energy Efficient Data Center Award)
* Certification scheme by DCA (Data Centre Alliance)
* Building certification by LEED (Leadership in Energy and Environmental Design) for building design and construction and operations and maintenance of DCs

In European Union, currently established notions are:

* Regulation on eco-design requirements for servers and data storage products EU 2019/42
* Energy Efficiency Directive (under Fit for 55 legislative package)
* EU Code of Conduct (CoC) on Data Centre Energy Efficiency

*The* EU 2019/42 regulation sets out the sustainable design practice requirements for data centre electronics but mostly focuses on server design. The subsequent Energy Efficiency Directive by European Commission proposed as part of the Fit for 55 legislative package (including policies that aim to lower net GHG emissions by at least 55% by 2030) outlines energy-related sustainability reporting requirements for data centre operators. Furthermore, the directive incentivises data centres to explore waste heat reuse potentials by requiring a cost-benefit assessment of waste heat utilisation in DCs above the 100kW capacity threshold. In February 2022, the forenamed directive was additionally strengthened to ensure data collection transparency and quality. The EU Code of Conduct on Data Centre Energy Efficiency is a very comprehensive, voluntary guideline for various DCI stakeholders, outlining best practices and setting out the targets and requirements for energy consumption reduction in a *“cost-effective manner without hampering the mission-critical function of data centres”*70*.* Furthermore, it is the only independent initiative which monitors energy consumption and has mobilised 290 participating data centres. As concluded by Avgerinou71, the EU Code of Conduct on DC Energy Efficiency is an incredibly effective non-regulatory act.

Additionally, a sustainability certification BREEAM (Building Research Establishment Environmental Assessment Methods) for data centres functions explicitly in the United Kingdom.

To allow for monitoring of the progress of any of the above measures, there is a need for standard practices and metrics. Different bodies, official, commercial, and non-profit, proposed an overwhelming number of metrics, making the scope difficult to navigate and causing inconsistencies in calculating practices. The primary triad of standardisation establishments in Europe are concurrent CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization), and ETSI (European Telecommunications Standards Institute). While ISO (International Organization for Standardization) and the International Electrotechnical Commission (IEC) are working jointly to develop international standards and guidelines, previously, many industry-developed metrics were subsequently standardised and officially approved. For instance, power usage effectiveness (PUE), water usage effectiveness (WUE) or carbon usage effectiveness (CUE), which were standardised by Green Grid - a non-profit industry consortium. The recent effort to create industry-agreed global standards is the *EN 5060051 standard series*, also known as *ISO/IEC 30134: Information technology – Data centres – Key Performance indicators*72. This series focuses on the energy and sustainability of data centres and consists of the following metrics:

* Power Usage Effectiveness (PUE),
* Renewable Energy Factor (REF),
* IT Equipment Energy Efficiency (ITEEsv),
* IT Equipment Utilisation of Servers (ITEUsv),
* Energy Reuse Factor (ERF),
* Cooling Efficiency Ratio (CER),
* Carbon Usage Effectiveness (CUE)
* and Water Usage Effectiveness (WUE).

The industry itself is leading innovation in many practices and standards. Further significant initiatives in the sector concerning energy efficiency and sustainability are Climate Neutral Data Centre Pact, Circular Economy for the Data Centre Industry (CEDaCI) and Open Compute Project (OCP).

**Climate Neutral Data Centre Pact**73

Since data centre operators and trade associations committed to the European Green Deal with ambitions to become climate neutral by 2050, an initiative – the Climate Neutral data centre pact, was formed in 2018. The initiative is a set of conformed actions across areas such as energy efficiency and conservation, clean (renewable) energy procurement, water conservation, circular economy, and governance. This self-regulatory initiative claims to be a one-step-ahead response to the upcoming 2024 EU regulations for the sector.

**Circular Economy for the Data Centre Industry (CEDaCI)**74

Another initiative, the Circular Economy for the Data Centre Industry (CEDaCI) project, pioneers building a circular economy for the sector in Northwest Europe. CEDaCI proceedings aim to raise awareness and increase equipment reuse and remanufacture while reducing e-waste rich in precious virgin materials and CRMs and securing a resilient and viable supply chain. Furthermore, the project advocates for improved Eco-design guidelines and product life extension and educates SMEs from various data centre subsectors about circularity-friendly decision-making and conscious hardware consumption.

**Open Compute Project (OCP)**75

OCP is a collaborative, transnational project based in Prineville, Oregon, in the United States. Its mission is to advance the efficiency, sustainability and scalability of data centre hardware and infrastructure. The unique selling point of this initiative is an innovative approach to reducing the complexity of the designs and manufacturing and strongly promoting the open-source approach over ownership.

1. Sustainability Reporting

Sustainability reporting aims to disseminate companies' non-financial information to increase transparency about business operations and showcase positive contributions to society. It can be voluntary or mandatory, depending on the nature of the business and region. As mentioned in section 2.2.3, in the European Union, sustainability reporting is mandatory for specific companies and outlined by the Non-Financial Reporting Directive (NFRD) and shortly by the Corporate Sustainability Reporting Directive (CSRD), whereas in the UK, it is not required but encouraged. Nevertheless, more mandatory reporting requirements are on the way. New policies are most likely to incentivise companies to report data by imposing penalties or similar forms of reprimand. In the EU, firms need to disclose specific environmental and social information; however, there is no standard format. Companies can use European, international, or national guidance, depending on their requirements. There are various initiatives including the Organisation for Economic Cooperation and Development Guidelines (OECD), United Nations Global Compact's Communication on Progress (COP), the International Integrated Reporting Council (IIRC) and leading guidelines from the Global Reporting Initiative (GRI), to name a few.

GRI is the independent, international body with the most extensive and widely relevant benchmark for sustainability reporting. GRI also acknowledged the private sector's significance in achieving SDGs and collaborated with the UN to encourage governments and businesses to measure their environmental, social, and economic contributions. As a result, GRI, together with the UN Global Compact and the World Business Council for Sustainable Development, designed the SDG Compass76 to guide on "how they can align their strategies as well as measure and manage their contribution to the realisation of the SDGs". It is, however, a directory of relevant business tools which might help build SDG reporting following GRI standards.

Sustainability reporting practices across all sectors, including the data centre industry, require an agreed, consistent approach. Sector-specific guidance is required to prevent misinterpretation, resulting in ineffective and inaccurate disclosures. For instance, more clarity on the span of companies' environmental and societal responsibilities is needed, especially in light of Scope 3 emission reporting, from which companies currently refrain, possibly because it accounts for the highest GHG emissions.

Sustainability reports vary between data centre providers and hyperscale cloud suppliers and large colocation companies tend to have a more meticulous approach and publish extensive environmental data, which they have collected over longer periods of time. To explore differences and similarities in disclosed metrics, several most recent (mostly from 2021, due to industry reporting period) sustainability reports, or equivalents available publicly on various companies’ websites, were reviewed (See Table X.1).

[Table X.1 near here]

For instance, the Environmental Report 202277 by Google, 2021 Sustainability Report78 by Meta, and 2021 Environmental Sustainability Report36 by Microsoftrecord detailed disaggregated data on Scope 1, 2 and 3 emissions, general energy data (including consumption, efficiency and renewable), and detailed water-related figures (covering consumption, withdrawal, and discharge). Additionally, Environmental Report 2022 by Google and 2021 Environmental Sustainability Report by Microsoft include carbon intensity and full waste-related statistics. Google and Meta reports follow GRI standards reporting practice, whereas document from Microsoft pursues the Sustainability Accounting Standards Board (SASB) guidelines. Sustainability Report 202079 by Virtus Data Centresincludes less information and significantly fewer statistics compared to the aforementioned reports. All reviewed reports disclosed data on renewable energy mix ratios and covered Scopes 1 and 2 of GHG emissions. Amongst those documents, reports by Equinix80, Google, and Metafeature energy efficiency data by presenting the PUE metric. Lastly, the 2021 Sustainability Report by Metastated the annual water usage effectiveness of their facilities.

The reason for differences in the amount of data and level of detail is possibly due to business size. The report by Virtus Data Centresis less exhaustive, possibly due to the fact that it is published by a much smaller business than other reports mentioned, which originate from companies that operate hundreds of facilities.

1. SDGs in Sustainability Reporting

Business plays a crucial role in sustainable development, and SDGs are setting the direction on which companies can reflect in their strategies and activities. Matters across climate change, resource consumption and production, biodiversity preservation, human health and wellbeing, and education are equally important to transnational governments and the private sector. Additionally, SDGs can bring new business opportunities in sustainable innovation and transformation, building reliable and worthwhile supply chains or engaging and shaping environmental regional and national policies.

However, companies should refrain from using sustainability reporting as a marketing opportunity or competitive advantage. A common practice is only to disclose positive and attractive details while ignoring unfavourable information, consequently altering the perception of the company's performance, called greenwashing. Furthermore, "SDGs-washing" and even "blue-washing" has been recognised, by declaring positive contributions to SDGs while ignoring the negative impacts and using the UN logo to proclaim sustainability without genuine action, respectively.

There are numerous reports on SDGs in the private sector. For instance, *SDG Compass*81 (by GRI, WBSCD and UN Global Compact), *SDG Industry Matrix*82, *Making the SDGs relevant to business*83 (by PRé -Sustainability & 2.0 LCA consultants), and many more. All those whitepapers aim to translate the SDGs to business needs and opportunities, provide sectoral guidance and educate for a sustainability-orientated business journey. Moreover, the PRé-Sustainability report encourages connecting SDGs to Life Cycle Assessment, and KPMG's *How to report on SDGs*84 proposes how to measure progress towards global goals. Moreover, SDGs opened a market for a myriad of tools and aids for building SDG-based business strategies. For instance, *SDG Action Manager*85*, SDG Monitor*86*, SDG Impact Assessment Tool*87. Different tools require a mixed level of previous sustainability and SDGs knowledge from the user and provide various options. Most often, those tools provide a platform to organise ideas for acting on SDGs. Though the overwhelming private sector guidance and platforms available, resources specific to the data centre sector are missing. The literature search only identified -one current study which discusses the sector's impact on the SDGs: "Tools Towards the Sustainability and Circularity of Data Centers"88. Unfortunately, the arguments given by the authors lack correct references. Besides, this investigation into SDGs in the DCI seems over simple and incomplete, leaving an unfulfilled research opportunity.

Studying the latest available sustainability reports and equivalents mentioned in the previous section (X.3.4.3), SDGs mentioned in the reports were identified and organised (See Table X.2).

[Table X.2 near here]

Most of the reviewed documents mentioned SDGs in their strategies, apart from the following: the Sustainability Report 2020 by Virtus Data Centres, 2021 Environmental Sustainability Report by Microsoft (a special report on SDGs was issued separately) and Environmental Report 2022 by Google (SDGs are not disclosed in the report, but Google takes part in the Business for 2030 Initiative). Although the approach and total number of SDGs mentioned varies, the 2021 Environmental Sustainability Report by Microsoft mentioned all 17 goals in their extensive document, which primarily focuses on four goals, including Goal 4. Quality Education, Goal 8. Decent work and economic growth, Goal 13. Climate Action and Goal 16. Peace, justice, and strong institutions; and showcases positive contributions to all other SDGs. Another report with comprehensive SDG coverage is 2021 Annual Sustainability Report Colt Group, which records not only goals but also associated targets. The other documents include seven or fewer goals. The most commonly declared SDGs are:

* Goal 7. Affordable and clean energy
* Goal 8. Decent work and economic growth
* Goal 9. Industry, innovation, and infrastructure
* Goal 13. Climate change (environmental dimension)
* Goal 17. Partnership for the goals

From which only Goal 13. links to the environmental dimension, and Goal 7. to the society. The remaining Goals, 8, 9 and 17, refer to the economy.

Commonly, the declared SDGs tend to record positive actions and most often refer only to business operations and direct employees while overlooking trade-offs or indirect implications. The selected SDGs appear to frequently fit into ongoing business community initiatives, such as education programmes, donations to charities, or similar projects, and it is difficult to ascertain whether the companies have plans to increase SDGs coverage in the future.

1. Conclusion & Opportunities for Further Research

The presence of data centre infrastructure is paramount to the digital economy. It transformed the traditional economy paradigms and enabled business innovation, automation, and instantaneous access to services as diverse as healthcare, leisure and entertainment and e-payments. During the recent coronavirus pandemic, the digital economy has allowed flexibility for working from home and delivering many traditional services digitally, significantly increasing the number of internet users and the volume of data traffic once more. There are countless examples of the economic and social benefits of the digital economy, but the environment remains a substantial trade-off. The DC infrastructure is hidden away in windowless warehouses, invisible even if located at the heart of a city. The 24/7 operations consume considerable amounts of energy, similar to the demands of some regions or countries. Moreover, evidence predicted that the future expects a further increase in energy usage due to the ever-rising demand for digital services. Furthermore, the thousands or millions of servers, other networking equipment, the extensive supporting infrastructure, and the facility structure all include embodied carbon footprints.

It is essential to utilise the whole-system approach (making sense of the complexity and interlinkages) and life cycle thinking (quantifying environmental impacts throughout products or services lifespan) to fully understand the influence of DCI on overall sustainability, equally positive and negative.  This chapter described examples of the favourable and damaging impacts aligned with the three pillars of sustainability - social, economic, and environmental - outlined by the *triple bottom line* definition. The scope of the demonstrated implications covered fundamental hotspots in the data centre life cycle, from materials extraction, through operations to electronic waste at the end-of-life, and sectoral and systemic challenges for the data centre sector. Simultaneously, the DCI sector has the potential to, directly and indirectly, contribute to the 2030 Agenda for Sustainable Development, which emphasises the digital economy and technology as integral enabling elements of the future world. Currently, a limited number of SDG goals and targets are mentioned in business sustainability/CSR/ESG reports, and documents frequently focus on SDGs that correspond to direct employees, GHG emissions, and community service projects. Moreover, SDGs are often used to demonstrate positive contributions while overlooking associated trade-offs. The data centre industry has the opportunity to directly influence several of the SDGs (See Table X.3).

[Table X.3 near here]

Furthermore, it is likely that the DCI can have an indirect impact on the following SDGs (See Table X.4).

[Table X.4 near here]

Nonetheless, due to the complexity and vastness of this unique sector, this subject requires further attention and investigation from researchers inside and outside the industry. In order to determine and translate relevant goals and targets for DCI, there is a need for multidimensional research into all SDGs in the sector's value chain and analysis of the industry landscape for opportunities and barriers. Future research should address the following research questions:

* Which UN SDGs are relevant to the Data centre industry?
* How can the goals and targets in the context of DCI be systematised?
* What are the synergies and trade-offs?
* How can DCI companies monitor and report on their progress towards Sustainable Development Goals?

This highlights the gaps in current practice and the need to consolidate relevant, cross-sectoral metrics and indicators, tools or frameworks and further explore challenges that stakeholders may face when reflecting on SDGs. Insights from the DC business stakeholders would be beneficial to identify the current approach to addressing and monitoring SDGs, the knowledge and awareness of the 2030 Agenda framework and the prospects of advancing the SDG progress within DCI. Such research would be of value to researchers and industry stakeholders working towards implementing UN SDGs in this extraordinary industry and could inspire other sectors.

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**FIGURE AND TABLE CAPTIONS**

*Figure X. 1 Data Centre Industry Sub-Sectors as Identified by The CEDaCI Project.* **Source (Authors), adapted from:**

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*Table X. 1 The Review of The Information Disclosed in Chosen Sustainability Reports***.**

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*Table X. 3 Examples of SDGs Goals and Targets Which the DCI Can Directly Influence.*

**Source (Authors), Reference:** United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. 2015**.**

*Table X. 4 Examples of SDGs Which the DCI Can Indirectly Influence.*

**Source (Authors), Reference:** United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. 2015**.**