Australia's National
Science Agency

Data Centres and the Australian Energy Sector

Stephen Lindsay, Kate Cavanagh, Terijo Lovasz

31 May 2021

National Energy Analytics Research (NEAR) Program

Commercial-in-confidence

Citation

Lindsay S, Cavanagh K and Lovasz T (2021) Data Centres and the Energy Sector. CSIRO National Energy Analytics Research (NEAR) Program, Australia.

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Acknowledgments

This project is being delivered under the National Energy Analytics Research (NEAR) Program. The NEAR Program is a joint venture between the Department of Industry, Science, Energy and Resources (DISER), the Australian Energy Market Operator (AEMO) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Glossary/ Abbreviations

Abbreviations	Definitions
AI	Artificial intelligence
CER	Clean Energy Regulator
Computing instance	A environment that can run computer applications and services that is either a physical computer, or a virtualised machine that may share physical computing resources with other virtual machines
GJ	Gigajoules
GPU	Graphics Processing Units
ICT	Information and communications technology
IT	Information Technology
kW	Kilowatt
MW	Megawatts
NABERS	National Australian Built Environment Rating System
NGER	National Greenhouse and Energy Reporting
PUE	Power Usage Effectiveness
t CO2-e	tonnes of carbon dioxide equivalents

Executive Summary

The world is becoming increasingly dependent on information and communications technology. The ‘backbone’ of the computing and networking infrastructure underlying these increasingly critical digital services are data centres (Masanet, et al. 2020) , which house the computing, storage and networking used to process, store and communicate data. Data centres currently consume about 1% of all electricity, a level that has not increased considerably in the last decade despite exponential growth in the number of internet users and connections during that time. This discrepancy is attributed to technology developments, specifically improvements in hardware efficiency, advancements in the management of cooling and heat dissipation, and more efficient utilisation of computing instances. Projections of how much electricity data centres will use as they continue to expand and evolve interest policymakers, energy network operators, data centre operators and environmentalists.

In the Australian context, there are limited sources of information with estimates and accounts of exactly how much energy is consumed in data centres. The data that is available from AEMO meters suggests data centres present a stable and predictable load to the grid, with a higher load in summer and a small increase in consumption during the middle of the days. Outside of regulation and programs aimed at the broader commercial building industry, there are no mandatory energy efficiency programs that target the data centre sector.

There is debate in the literature regarding the trajectory of data centre energy consumption, and there are divergent estimates about the potential impact of ongoing growth in the sector. There is, however, a consensus around the need to monitor this closely. Even if the most optimistic estimates of energy sector impact by data centres are accepted, without accurate data it will be difficult to understand which of the scenarios has come true and at what point in the future any changes in the profile of data centre energy consumption will require policy interventions or other mediations.

Based on our review of the literature, the sector, and publicly available data, we make the following recommendations:

- AEMO data should be further leveraged to answer specific questions about the current state of the sector and its recent trajectory. This will provide a foundation for an accurate and reliable baseline that can quantify the growth of the sector and its localised impact on specific areas of the grid.
- Activities that promote greater discussion and knowledge sharing between data centre operators, energy network businesses, the energy market operator, government policy teams and the research community should be pursued and formalised.
- Future policy development, whether it concerns energy efficiency policies or standards to promote more effective utilisation of computing resources, changes in procurement guidelines to encourage the use of more efficient cloud platforms or other strategies to reduce the impact of data centres on the grid, should be accompanied by appropriate data collection strategies to ensure the impact of the intervention can be adequately measured and assessed.

1 Introduction

The upheaval across the world in 2020/21 resulting from the impact of the Coronavirus pandemic has highlighted the increasing dependence of society on information and communications technology (ICT). As communities around the world have moved through varying levels of restrictions on gathering and movement, demand for services delivered over the internet has not only increased significantly – with reports of a 40% increase in internet traffic during the period of February to April during the first wave of the pandemic in 2020 (Sandvine, 2020) – it has increased in criticality. As citizens experienced (and in many cases, are still experiencing) 'lock-downs' of varying severity around the world – being encouraged or obliged to conduct as much of their daily life from home as possible – video conferencing and collaboration platforms have become increasingly critical for workplaces, health services and governments to function effectively during the pandemic. The 'backbone' of the computing and networking infrastructure underlying these increasingly critical digital services are data centres (Masanet, et al. 2020), which house computing, storage and networking used to process, store and communicate data (Geng, 2015).

While the pandemic has drawn attention to the critical role of ICT in modern society, the underlying trend of global internet traffic has been one of rapid growth for many years. The number of internet users has doubled since 2010 and the internet traffic resulting from that growth has gone through a 12-fold increase during the same time (IEA, 2020). Independently of the impact of the Coronavirus pandemic, increasing digitalisation, the growth of mobile computing devices, the growth of AI/machine-learning powered analytics and services, growth in machine-to-machine communication to support commerce and increasing available capacity from developments in both fixed and mobile communications infrastructure means that internet traffic is forecast to grow exponentially for at least the next few years (IEA, 2020). Data centres will not only be a crucial component of this expansion, the way they are constructed, operated, located and utilised will develop and transform with these rapidly changing workloads.

Energy supply is a crucial consideration in the design, placement and operation of data centres. This report examines the intersection of the rapidly evolving data centre industry with the Australian energy sector. This report will aim to address the following questions:

- For the present:
  - What defines a data centre?
  - What do we know about data centre energy consumption?
  - What commercial, regulatory and technological trends drive current energy consumption?
- In the future:
  - What sector trends will affect future data centre energy consumption, and at what time horizon?
  - What can we say about future data centre energy consumption in Australia?

This project is part of the National Energy Analytics Research (NEAR) Program's 2019/20 work plan. Information presented in this report comes from two principal sources:

1. A review of both international and Australian literature pertaining to data centres and trends/drivers of data centre energy consumption.
2. Interviews with Australian data centre operators/experts and energy sector participants.

There is a paucity of reliable literature on the data centre sector, particularly for Australia. Of particular concern is difficulty in obtaining primary sources for figures that are published in the media. In this report we have, where possible, focussed on primary sources and have not included unverified figures from public reporting.

2 What is a data centre?

Data centres are ‘home to [the] computational power, storage and applications necessary to support an enterprise business’ (Khan & Zomaya, 2015). Data centres grew out of the server rooms where IT equipment was consolidated as functions of businesses became increasingly computerised. While this definition highlights what a data centre *does*, it doesn’t capture the diversity of the sector – ‘data centres’ encompass a very wide range of commercial and technical concerns. Data centres can be classified along several dimensions:

- **Ownership and operations:** whether the infrastructure is owned and managed by the enterprise for which the computation and data stored within the data centre is being performed, or on behalf of another organisation.
- **Location:** traditionally, servers were in rooms within existing buildings owned and operated by a company. As the sector has developed, computation and data storage has increasingly moved away from server rooms managed on-premises to offsite externally managed facilities.
- **Size:** data centres may be characterised by the number of servers or cabinets/racks that are managed within the data centre, by floor space, by energy consumption, or by other physical metrics that to classify the size of the data centre.
- **Reliability and security guarantees:** the tolerance of a data centre to operational impacts is typically described by four rating tiers that characterise the extent to which a data centre can endure the loss of one or more critical components. A Tier 4 data centre, for example, will maintain functionality irrespective of ‘almost all physical events’[1], whereas Tiers 3, 2 and 1 have decreasing amounts of redundancy for critical components and concomitant reductions in guarantees of reliability.
- **Services:** data centre services can be characterised by both who the service is being provided to and the nature of the service that is being provided, including:
  - services that are wholly consumed by the company that owns and runs the data centre
  - services that are consumed by a third party, including:
    - supporting services and infrastructure (physical space, power, networking, racks, security cages)
    - provision of physical computers
    - provision of software services, including:
      - access to operating systems, virtualisation or container services
      - access to software/application platforms.

There is not a formal classification for data centres that encompasses all these parameters; data centres are typically classified in the literature by the services they provide, who they are provided

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[1] http://www.tia-942.org/content/162/289/About_Data_Centers

to and the size of the data centre operation. Table 1 outlines the classifications that are used in this report and highlights the challenge of discussing data centres as a singular concept, particularly regarding their intersection with the energy sector. For example, an enterprise that runs its own dedicated data centre will encounter a different set of commercial, technical and regulatory drivers/barriers to pursuing increased energy efficiency in its data centre than a vendor offering cloud-scale services to thousands of businesses.

Table 1 Data centre classification

Class	Services provided	Ownership/operations	Location of computing resource relative to primary user
Enterprise	Internal to enterprise	Owned/operated by a company that utilises the services of the data centre.	Can be onsite or offsite.
Colocation	Physical space, networking, power and other non-computing services provided to third party enterprises.	Colocation provider leases space and supporting services to third party.	Offsite from the enterprise that is utilising the computing infrastructure.
Cloud/Hyperscale	Virtualised server infrastructure, application platforms, storage services, middleware services, etc.	Depending on the market, data centre owned and operated by the service provider or utilising colocation services offered by other providers	Offsite from the enterprise utilising the computing services.
Edge	Emerging class of data centre expected to provide a variety of services in environments where communication latency is important.	Data centre owned and operated by the service provider.	Location determined by, for example, the specific latency requirements of an application.

Physical parameters of data centres like floor space and energy consumption illustrate the breadth and diversity of the Australian data centre landscape. While colocation data centres in Australia operate with reported energy capacities ranging from hundreds of kW to hundreds of MW, and floor space estimates that are typically in the single thousands of meters squared, a hyperscale providers operate data centres in Australia with rated energy capacities well over 100MW and floor space of 35,000 meters squared [2].

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[2] For example, see https://www.airtrunk.com/location/syd1-sydney-west

The commercial environment for data centres in Australia is also somewhat complex. Operators such as NEXTDC or Equinix provide colocation services directly to commercial customers, as well as providing onshore facilities for cloud providers like Amazon Web Services. Besides the use of onshore colocation services, Amazon Web Services also operate their own physical data centres. They will deliver the commercial services they offer from a mix of facilities that they own and operate in Australia, facilities that are run by colocation providers, and data centres that are located overseas.

‘Edge’ data centres add an additional level of complexity, both in terms of their size and location, but also in terms of definition. Interviewees described the entire Australian market itself as an ‘edge’ market – services are in Australia and other regional hubs such as Singapore to address a range of concerns that include reducing the latency for services that might otherwise be delivered from the US or Europe. While ‘edge’ is typically discussed as a response to the latency requirements for new technology, in Australia ‘edge’ is as much a function of the distance between major population centres and the technical services that are required in those regional hubs. While the bulk of commercial data centres in Australia are in major cities – in particular Sydney and Melbourne – providers are progressively rolling out new data centres in regional centres like Newcastle, Tamworth and Dubbo[3] to meet a growing need for reliable digital services in regional Australia. Edge data centres in these regional areas not only contend with the challenge of finding land to build a data centre with the proximity to fibre and electricity infrastructure but must also compensate for local weather risks and building the data centre to account for Probable Maximum Flood (PMF) standards.

Enterprise data centres present the biggest challenge to developing a complete understanding of the Australian data centre market. There are no reliable figures for the number of enterprise data centres in Australia or their energy consumption. While we discuss the transition from the enterprise to third-party data centres in this report and discuss internationally reported trends in, for example, the ratio of the amount of computation that is performed at in-house data centres to colocation or cloud providers, we do not describe the enterprise data centre ecosystem in any significant detail.

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[3] https://www.leadingedgedc.com/locations

3 The evolving data centre sector and energy consumption

The data centre industry is evolving in multiple dimensions that apply to energy consumption. In this section we will consider the key commercial, technological, and regulatory drivers that are pertinent to development of the sector, and their relationship to energy.

3.1 Commercial drivers

The data sector market is undergoing significant structural change (Flexera, 2021). Traditionally, enterprises operated their own server rooms, data centre, or data centres – having to manage the design, planning, operation, upgrades and support of their own critical infrastructure. Today, many businesses are increasingly utilising third parties to provide information technology and data centre services. This can range from changing the location of ICT equipment from an in-house data centre to suppliers of space for that infrastructure – where the nature of the load and service has not changed significantly but is now in a building operated by a colocation provider – through to utilisation of services where the underlying computing infrastructure has been abstracted out of the purchase and the organisation procuring access to software services and platforms may have no knowledge or interest in the underlying physical infrastructure. This change is not just a movement of business activity from one company to another, it can represent a change in the type of work that is done – for example, in the utilisation of new machine learning services that are not part of an enterprises core expertise – to the amount, cost and – because hardware may be utilised more efficiently at scale – the energy intensity of the computational work that is performed. These structural changes and the pace at which they are occurring present challenges to analyses of data centres because they create problems of definition (what is a data centre?), comparison (does it make sense to discuss small private data centres in the same conversation as massive cloud service operators, or 'hyperscalers'?) and forecasting (how do you baseline a sector undergoing rapid and profound structural change?).

The pace of this change is exponential. Between 2010 and 2018, global data centre computing instances increased 550%, with smaller traditional data centres hosting 79% of the world's computing instances in 2010 but with 89% of instances having moved to cloud-based infrastructure by 2018 (Masanet, et al., 2020). A 2021 survey of a variety of businesses across the globe found that 99% were using some type of cloud-based service, with 50% of their workloads and 46% of the organisation's data in a cloud. The small businesses surveyed (those with less than 1000 employees) had more of their workload and data in some sort of cloud than larger businesses. It is predicted that 57% of commercial workloads and 54% of data will be cloud-based within a year (Flexera, 2021).

Changes in how businesses deploy their enterprise computing load is not the only significant market shift. As described above, the number of internet-connected users, and the amount of internet traffic they generate, has grown enormously over the last decade. The rate of growth in that traffic is expected to continue to increase in the immediate future (IEA, 2020). Growth in internet traffic – and therefore in the associated data centre load – is coming from a variety of sources (Cisco, 2020), such as:

- large increases in the number of mobile computing devices, projected to increase from 8.8 billion in 2018 to 13.1 billion by 2023
- growth in transmission of high-definition entertainment, including games, streaming movies and television programs
- growth in demand for video-based communication services.

Increases in network bandwidth, whether through wired or wireless infrastructure, has a multiplication effect – not only can more traffic be sent and received in a short time, but higher transmission rates encourage the development and use of services that previously would not have been feasible.

3.2 Technology drivers

In addition to the structural market changes that are occurring in the sector, the technology utilised within data centres has undergone significant change, with many of these changes resulting in decreased energy consumption. Efficiencies have been gained through improvements in processor design, cooling systems, system utilisation, and reductions in idle power usage (Masanet, et al., 2020). Data centres are effectively becoming denser, with increasing amounts of computation being performed in smaller physical spaces and relatively fewer resources being consumed per computing cycle. The literature on technology changes in the data centre industry is extensive and highly technical; Brochard (2019) provides a comprehensive overview that covers the following in much more detail. Here we will highlight of some key technology developments that apply to data centre energy consumption and efficiency.

There are multiple facets of data centres and their workloads that are pertinent to energy consumption:

- computing infrastructure (servers, storage, networking) and their subcomponents (processing units, memory, storage devices)
- non-computing infrastructure (cooling systems, uninterruptible power supplies, lighting)
- the nature of the computing workload and how it is distributed into the computing infrastructure.

The server's processing units are the server components that process data and instructions and handle a significant amount of the power consumed and heat that is generated by the server (Brochard, et al., 2019). Key developments in processor technology include increasing transistor density[4], increases in the number of computing cores per processing unit, and a degree of processor specialisation, in particular the development and use of Graphics Processing Units (GPU) and related technologies for computing tasks requiring high degrees of parallelisation (e.g. some machine learning tasks).

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[4] Largely tracking with Moore's Law, which states that the number of transistors in a chip will double every 18 months to 2 years.

A key non-computing concern for data centre design and operation is the removal of heat, first from the server, and then from the data centre itself. Most of the energy consumed by a data centre is converted into heat and computing components (processors, drives, etc.) have limits on the range of temperatures that they can effectively operate at (Brochard, et al., 2019). Key developments include changes in the manner in which components are arranged within the server to optimise airflow, the placement and construction material of components designed to dissipate heat from the server (heat sinks, rack cooling systems) and the layout and design of the rooms in which servers are stored. There are many innovations in this area, including:

- using waste heat for district heating, for instance from the Westin Building Exchange data centre in Seattle to heat the Amazon offices across the road, resulting in reduced consumption of electricity for both buildings (Clancy, 2017)
- exploring the use of data centre waste heat for greenhouse-grown edible food in sub-arctic regions (Ljungqvist, et al., 2021)
- implementation of new technologies at Syracuse University's Green Data Center to reduce power loss, increase efficiency and reuse waste energy, resulting in a facility that uses 50% less energy than a typical data centre (Blair, 2013)
- using data centre waste heat to create conditions in a laboratory that are projected to be caused by climate change through 2050, in order to research mitigations for those conditions (Data Center Knowledge, 2010).

In addition to the changes in the design and implementation of the physical components of data centres, the way computing loads are distributed on servers has also changed. In a traditional data centre, a physical server may have been dedicated to a single application (Bari, 2013) resulting in inefficient utilisation of that hardware (Guan, 2017). Key developments in the more effective utilisation of hardware include the growth of technologies designed to facilitate the efficient provision of multiple operating systems and/or applications on a physical server (virtualisation, containerisation, orchestration), changes in procurement models for computing resources (utility computing, infrastructure-as-a-service) and a movement from procurement of computing resources for running applications (whether physical or virtual) to procurement of network-accessible third party application services that are accessed via the internet.

3.3 Regulatory drivers

3.3.1 International regulation

Internationally, the most significant regulations that have intersected with the operation of data centres have been those focussed on the management of information within the data centre for privacy/confidentiality or financial compliance – examples include the European Union's General Data Protection Regulation (GDPR)[5] and the United States Health Insurance Portability and Accountability Act (HIPAA)[6]. While, at the time of writing, the energy efficiency of data centres has

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[5] https://gdpr.eu/what-is-gdpr/

[6] https://www.cdc.gov/phlp/publications/topic/hipaa.html

not been subject to the same level of regulation by legislatures around the world, there are active discussions concerning the topic.

In ‘Shaping Europe’s Digital Future’ (European Commission, 2020), the European Union, recognising the significant size of the sector and its potential impact on emissions, has outlined a goal for the industry to achieve carbon neutrality by 2030. A follow-up report, ‘Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market’ (Environment Agency Austria & Borderstep Institute, 2020), outlines several recommendations aimed at ameliorating the ongoing impact of data centres. These include the development of guidelines, certifications and changes to government procurement rules to encourage uptake of more efficient cloud services. As yet, however, there are no new regulations that impose direct energy efficiency requirements on data centres in the European Union. In response to the developing discussion on emissions goals and the possibility of regulation, many data centre operators and trade associations operating in Europe are committing to a self-regulation scheme that outlines an aim of making ‘data centres climate neutral by 2030’[7]. This is to be achieved by setting specific Power Usage Effectiveness (PUE, see Box below) targets for data centres, purchasing ‘carbon-free’ energy and working with governing bodies on the development of metrics to measure energy efficiency more effectively. These goals align with announcements by some major cloud providers operating outside the EU. For example, both Microsoft[8] and Google[9] have made public commitments to not only offset carbon emissions from their current operations but also to address their historical emissions.

Power Usage Effectiveness (PUE)

The industry standard measure for measuring the efficiency of a data centre is Power Usage Effectiveness or ‘PUE’. PUE is the ratio of the energy used to power the entire data centre to the energy specifically used by computing equipment (Brochard, et al., 2019) with the ideal PUE being 1 (i.e. energy is only utilised for ICT functions). Traditional data centres used approximately half of the energy they consumed on non-computational loads like cooling, resulting in a PUE of approximately 2 (Geng, 2015, Brochard, et al., 2019), while large cloud providers like Google report PUE’s for their data centres of 1.11 (Google, 2021). While there are debates in the sector as to the utility and comprehensiveness of PUE as a measure (Brochard, et al., 2019), the distribution of progress towards the theoretical limits of PUE across time, data centre size and market position provide a useful map of the technological changes happening in the sector that are of relevance to energy consumption.

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[7] https://www.climateneutraldatacentre.net

[8] https://news.microsoft.com/climate/

[9] https://sustainability.google/commitments/

3.3.2 Australian regulation

Outside of regulation and programs aimed at the broader commercial building sector (National Construction Code, for example), there are no *mandatory* energy efficiency programs that directly target the Data Centre sector. The National Australian Built Environment Rating System (NABERS) has a set of voluntary assessments that ‘provide an indication of the operational energy efficiency and environmental impact’ of a data centre. This scheme is discussed in more detail in the next section when we look more closely at what information is available to describe the current state of energy consumption by data centres in Australia.

4 Data centres and energy consumption

Against the backdrop of a rapidly changing sector that is evolving to meet a growing dependence on internet-based platforms and services to support economic activity along with a growing demand for services to support an increasingly digitalised society, there is emerging discussion about the impact that the infrastructure underpinning these internet services has on the environment (Clifford, 2019). Along with concerns about electronic waste and water use, the intersection of the data centre industry with the energy sector is attracting attention from policymakers, energy network operators and environmentalists. The International Energy Agency (2020) estimates that data centres account for 1% of the world's electricity consumption and forecasts for growth in internet traffic over the coming years are accompanied by a concern that demand for electricity will also grow, along with concomitant greenhouse gas emissions. Where appropriate, governments can use regulation and reporting requirements to push sectors to use energy more efficiently to, for example, help meet greenhouse gas emission targets. It is, however, not a trivial task to assess whether a sector has potential for energy efficiency gains, whether regulation or reporting is an effective tool for realising those gains, and whether the gains justify the costs of rolling out the program to that sector. The data centre industry is rapidly developing, but what is not well understood are the magnitude and drivers of current energy consumption, and, equally important, the likely magnitude and drivers of *future* energy consumption.

Absolute energy consumption is not the only concern. Growth in the size, number and nature of data centres has the potential to have localised effects that go beyond the impact of data centres on electricity consumption that is often cited at the level of 1% energy consumption. For instance, in Ireland and Northern Ireland, the creation and expansion of data centres will be a key driver of significant increase in future electricity demand, and may cause up to 29% of overall demand in that region by 2028 (EirGrid and SONI, 2019). Data centres cannot be located just anywhere – as currently implemented, they require access to key communications hubs, a reliable supply of utilities (electricity and water for cooling), appropriate climate conditions and awareness of and preparation for potential natural disasters in the candidate location (Geng, 2015). Besides the physical parameters that dictate locations for data centres, changes in demands for low-latency communications, new mobile network infrastructure, population movements and changes in consumption patterns that the COVID-19 pandemic is creating are driving the development of 'edge' data centres. Edge data centres have the same devices as other data centres with a smaller footprint. These can be at the periphery (the physical edge) of a network and closer to end users than larger centres, resulting in faster service and high performance with minimal latency, which can be vital for organisations dealing with the Internet-of-Things, large data sets, etc. In other cases, 'edge' centres are physically closer to the network core, which also reduces latency for applications such as cloud-assisted driving or high-resolution gaming (Young, et al., 2021).

In interviews, data centre operators voiced concerns about the intersection of their industry with energy supply. Beyond the need for stable and reliable energy supply, rapid growth in the sector may require access to grid connections and supply that was otherwise unplanned. The planning, approval and augmentation cycle for distribution network infrastructure in Australia operates on multi-year cycles[10], periods of time in which the growth and deployment of a whole new generation of unforeseen internet enabled devices can occur. Electric vehicles, for example, may not only require forecasting and planning to address the impact of the required charging infrastructure for many additional vehicles, there may also be a need to plan for the edge data centres that will support the communication and coordination requirements of a new fleet of non-stationary, internet-connected, digitally sophisticated devices that require low-latency communications. Planning cycles for distribution networks were designed when forecasting changes in electricity demand was a less complex problem; the same cycle applied to a fast-developing sector like data centres may be more problematic.

Despite significant growth in the number of internet users and connections over the last decade, the energy consumption attributed to data centres has not grown considerably (IEA, 2020) (Figure 1). The disconnection between growth in data centre activity and relatively flat energy consumption is attributed to the key technology developments that were described in more detail in Section 2, specifically improvements in hardware efficiency, advancements in the management of cooling and heat dissipation, and more efficient utilisation of computing instances (Masanet, et al., 2020).

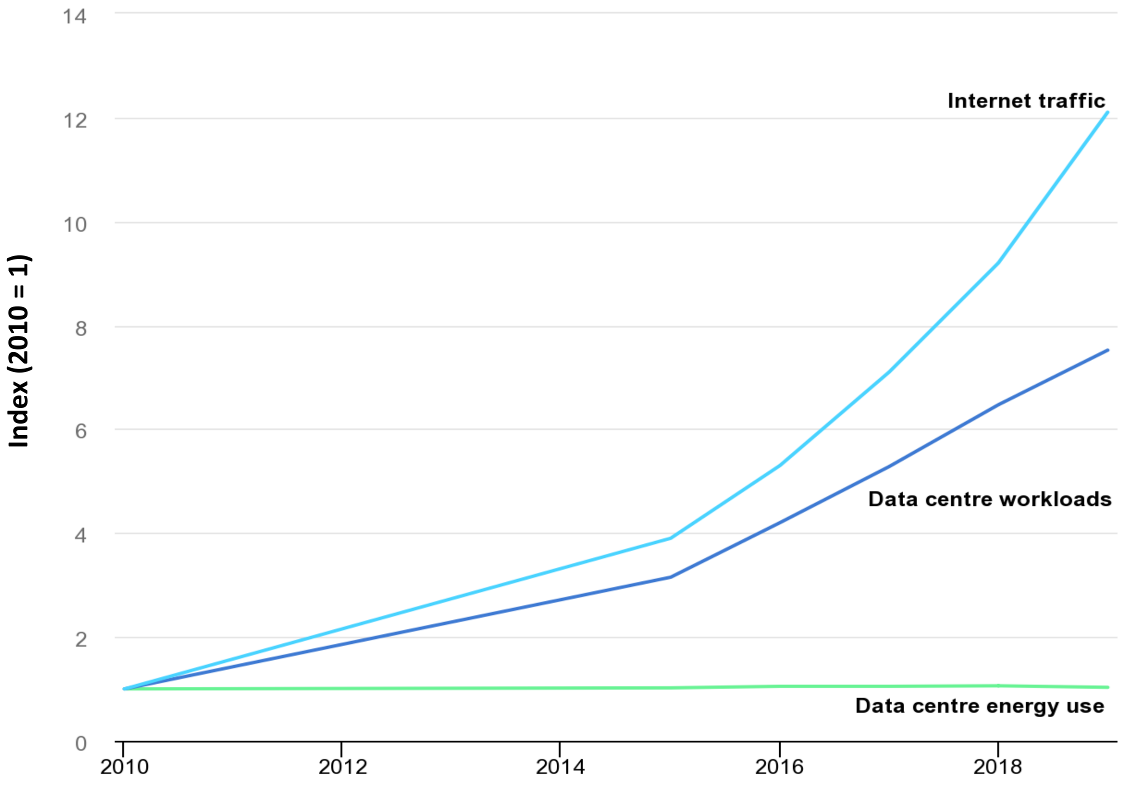

Figure 1 Global trends in internet traffic, data centre workloads and data centre energy use, 2010-2019, IEA, Paris

Source: https://www.iea.org/data-and-statistics/charts/global-trends-in-internet-traffic-data-centre-workloads-and-data-centre-energy-use-2010-2019

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[10] Especially the Australian Energy Market Commission five-year regulatory cycle; see https://www.aemc.gov.au/energy-system/electricity/network-regulation

A key question facing the data centre industry and energy sector participants is whether this trend can be maintained, or whether the growth in traffic will overwhelm any improvements made in operational effectiveness and, therefore, whether the energy consumption of data centres will increase and at what rate. This question is the key motivation for this report.

The ability and capacity of the data centre sector to respond to questions of ongoing energy utilisation and resulting greenhouse gas emissions is related to the structural questions discussed above concerning the diversity of data centres and the movement of computing loads away from on-premises data centres. Very large sector participants ('hyperscalers') have different capabilities and incentives – and a significantly larger energy consumption to manage in absolute terms – to the operator of a small, private data centre. Significant commitments have been made by some larger participants in the industry to utilising renewable energy to power their data centres and offsetting (and sometimes reversing) the emissions that can be attributed to their operations (IEA, 2019). The significance of such commitments is ultimately a function of the proportion of the market that they service (both now and into the future) and the manner in which data centre operations are defined (only those data centres directly operated versus data centre facilities procured through other operators, for example). There is a trend for more of the data market to be held by hyperscalers (Figure 2), as evidenced by the fact that in 2019 the world's largest cloud providers grew their market footprint by 21% during a period in which there was only a 10% growth in the commercial service-provider data centre market as a whole (Macquarie Data Centres, 2020).

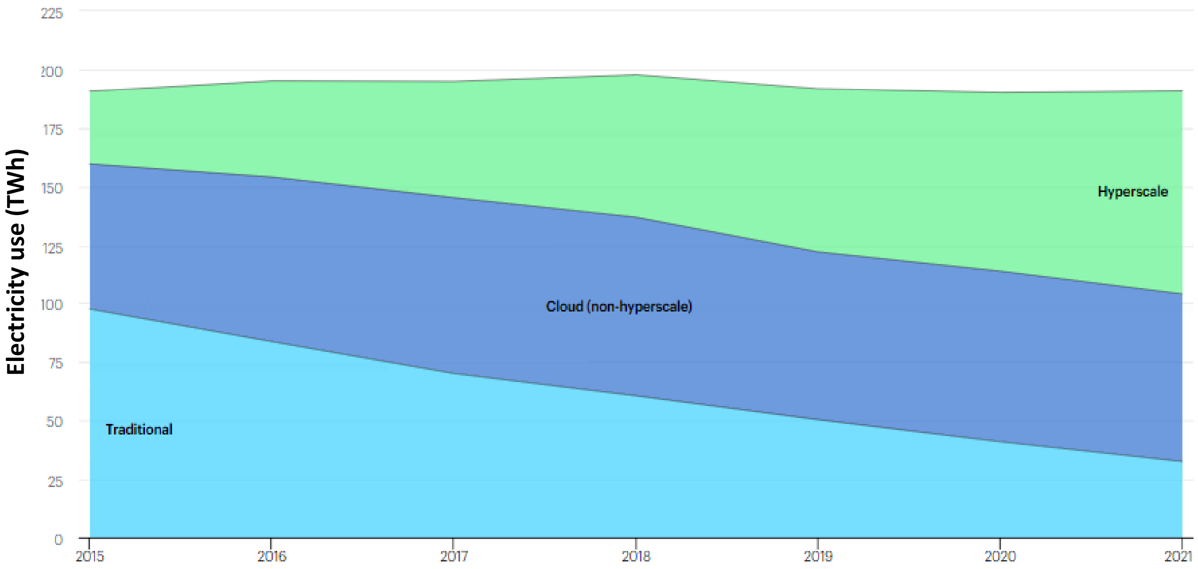

Figure 2 Global data energy centre demand by type

Source: IEA, Global data centre energy demand by data centre type, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-data-centre-energy-demand-by-data-centre-type

In addition to questions of efficiency, there is a growing discussion about data centres providing energy services to the grid, for example, by operating as a virtual power plant (Awasthi, Chalise, & Tonkoski, 2015) and participating in demand response activities (Bajracharya, et al., 2016). To maintain operation of the data centre in the event of a loss of energy supply, data centres maintain backup power systems. These systems are typically underutilised (due to the infrequency of power loss events) and, data centres generally have a stable, predictable load pattern. These combined characteristics provide opportunities for data centres to provide energy services to the grid, either by discharging at times of demand, or storing energy at times of oversupply. Interviewees indicated that this was actively being pursued in Australia, however insufficient information was provided to the authors to understand the magnitude and maturity of this development in the Australian sector. Interviewees suggested that smaller Edge data centres may be better placed to offset their operations with onsite generation as a result of their lower energy consumption, however, solar PV, for example, requires sufficient land to be available. Interviewees commented on a growing public concern regarding emissions and increasing pressure on companies to demonstrate action on sustainability measures.

4.1 Current data centre energy consumption in Australia

There are limited publicly available figures that quantify energy consumption in data centres. Estimates of current global data centre energy consumption vary, both in the estimate's value and the method used to derive it. The statistic reported by the International Energy Agency (2020) – that data centres account for 1% of global energy consumption – is based on the work of Masanet et al. (2020), which estimated global data centre energy consumption for the year 2018 at 205 TWh. Methods for estimating consumption (and future use) are discussed in Section 5.

In Australia, there are limited sources of information on either estimates or accounts of exactly how much energy is consumed in data centres; here we discuss Cloudscene, NABERS, NGERS, and the NEAR Program.

4.1.1 Cloudscene

Cloudscene is a procurement platform for enterprises to find colocation data centre providers and other ICT services. The service is not intended to provide information for research, however their publicly available data provides some high-level information about the state and size of the data centre sector in Australia (for example, at the time of writing there are 273 colocation service providers in Australia (Cloudscene, 2021)). Their terms of use forbid harvesting detailed information about individual data centres and therefore the publicly accessible data on their website is of limited value for a study such as this. It is, however, a useful resource for interested parties to explore information such as reported energy capacities and the floor space of Australian colocation data centres.

4.1.2 National Australian Built Environment Rating System (NABERS)

The National Australian Built Environment Rating System (NABERS) is a building rating scheme managed by the NSW Department of Planning, Industry and Environment that provides a sustainability rating for several building types, including Data Centres (NABERS, 2020). The system aims to improve the sustainability of buildings by providing reliable, repeatable, comparable ratings of building performance that encourage building owners to improve the quality of the building stock. Ratings for Data Centres are voluntary and based on Power Usage Effectiveness (PUE). NABERS provides three rating types for Data Centres:

1. **IT Equipment:** This rating is for companies that have their servers in a colocation environment where they have control over the computing equipment installed and how the computing equipment is utilised, but not the support services provided by the colocation operator.
2. **Infrastructure:** This rating is complementary to the IT Equipment rating. It is a rating for colocation operators to measure the efficiency of the supporting infrastructure they provide (air conditioning, lighting, etc.) but the not the computer infrastructure.
3. **Whole facility.** This rating is the combination of the IT Equipment and Infrastructure rating.

Data collected as part of NABERS ratings is publicly available and includes yearly energy consumption (actual, not planned), PUE, greenhouse gas emissions attributable to the building and a star rating. In its current state, the NABERS data centre database is only of limited value in providing insight into the current state of energy consumption by Australian data centres, because of the following factors:

- At the time of writing there are only nine NABERS-rated data centres (refer to Figure 3). This is less than 5% of the number of colocated data centres in Australia figures reported by Cloudscene.
- All the ratings are ‘infrastructure’ ratings, so there is no information regarding the efficiency of the computing equipment within the facility.
- The measure is voluntary. Interviewees suggested that there is a skew towards more recently developed energy efficient data centres and that therefore the rated buildings do not give a reliable account of the likely state of the sector.
- The measure is based on PUE. The literature (for example, Brochard, 2019) discusses the limitations of PUE as a measure – for example, it doesn’t address how effectively the energy is being used in performing computations, just the extent to which it is being used *for* computation rather than other services within the facility – and interviewees had some scepticism regarding the utility of PUE as a measure of efficiency because of differences in interpretation about which services within the facility are included in the calculation.

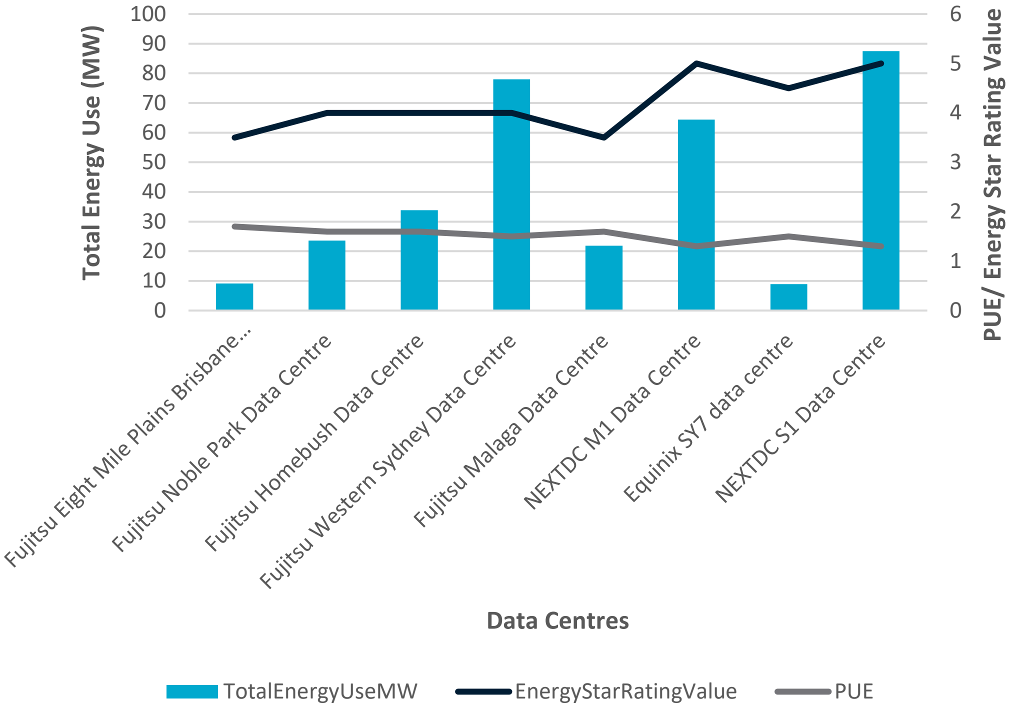

Figure 3 Data Centre energy use, NABERS Rating

Source: https://members.nabers.gov.au/PublicPages/RatingRegister/RatingRegister.csv

4.1.3 National Greenhouse and Energy Reporting (NGER)

The National Greenhouse and Energy Reporting (NGER) scheme, which is administered by the Clean Energy Regulator (CER), is a reporting system designed to capture data about energy production and consumption (and associated greenhouse gas emissions) from companies that, for a facility or across all corporate group activities, exceed defined thresholds for:

- greenhouse gas emissions
- production or consumption of energy.

The aim of the program is to capture data from companies with energy-related activities that are of sufficient magnitude to apply to policy development, international reporting obligations and other government activities that require detailed information about emissions from Australian enterprises.

The NGER dataset includes activities from several corporations that are active in the data centre or managed service space. Figure 4 shows energy consumption based on information reported to the Clean Energy Regulator in 2019-20 for some of the larger corporations that are involved in the management of data centres. While this information captures energy consumption, its utility is limited by the nature and granularity of the reporting – NGERS figures are publicly reported at the whole-of-business level for very large consumers, and without a detailed characterisation of the underlying entity (e.g., percentage of energy consumption by data centres rather than other corporate services, number of data centres operated by the company) it is difficult to draw firm conclusions about the data centre load based on NGER data alone.

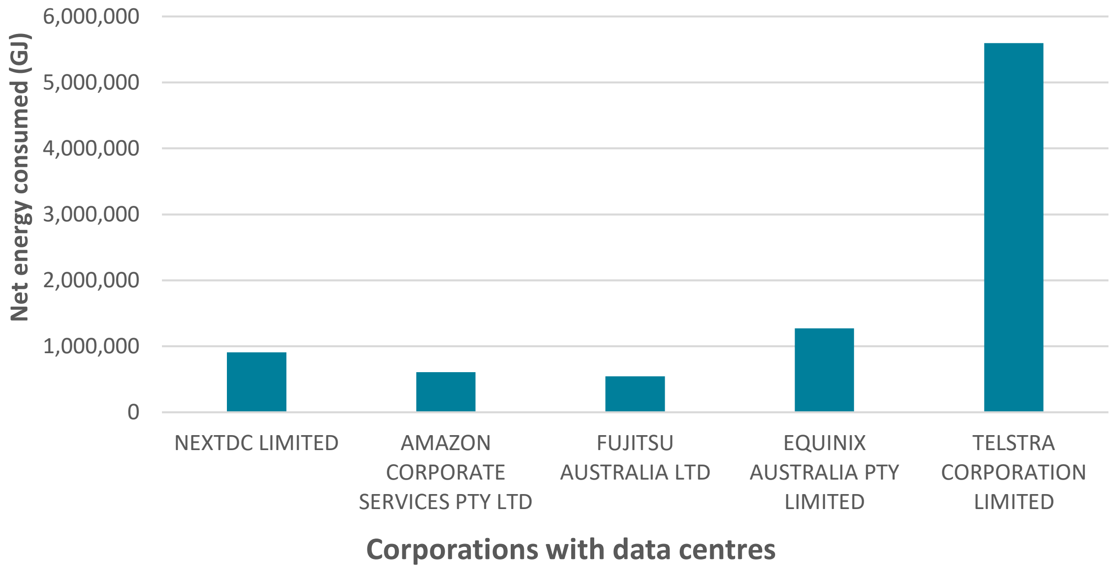

Figure 4 Examples of net energy consumption (GJ) of corporations with data centres as reported to NGERs
Data Sourced from:
http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/Corporate%20emissions%20and%20energy%20data/corporate-emissions-and-energy-data-2019-20

4.1.4 Australian Energy Market Operator (AEMO) Data

As part of the data sharing arrangements between CSIRO and AEMO that exist under the National Energy Analytics Research (NEAR) Program, the NEAR Program has limited access to aggregated AEMO meter data. For data centres, this means that NEAR can obtain load profiles for groupings of data centre sites, with the resulting load profile providing the total consumption for that group of buildings. While limited data was available at the time of writing, we have produced some preliminary datasets that demonstrate the potential value of this data source for characterising data centre energy consumption in Australia (the locations of these data centres are presented in Figure 5). Figure 6 shows the aggregate monthly profile for a collection of 14 small data centres (those with capacity ratings between 1 and 10 MW) located across Australia for the financial year 2019-2020. Figure 7 shows a monthly profile for a collection of 12 larger data centres (rated at greater than 10MW) for the same period. In both cases, the aggregate profile is mostly flat across the entire period, suggesting that the impact of these data centres on the grid in terms of overall consumption is stable and predictable. Replicating this for multiple years would present a picture of any increase or decrease in consumption and would help address whether growth in data centre load is just a function of new data centres being built, or if consumption in existing data centres is also changing. At the time of writing, however, that data was not available.

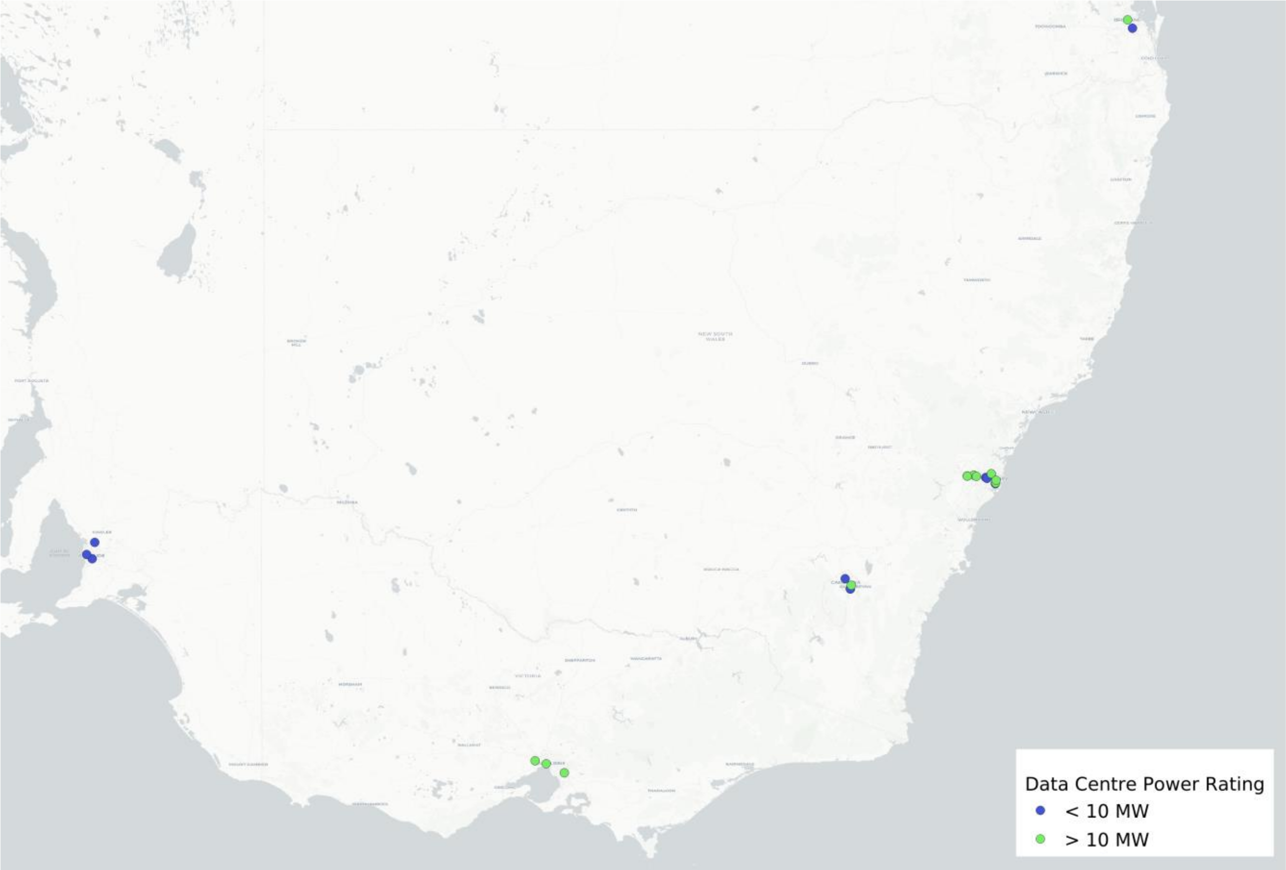

Figure 5 Location of data centres described by AEMO data

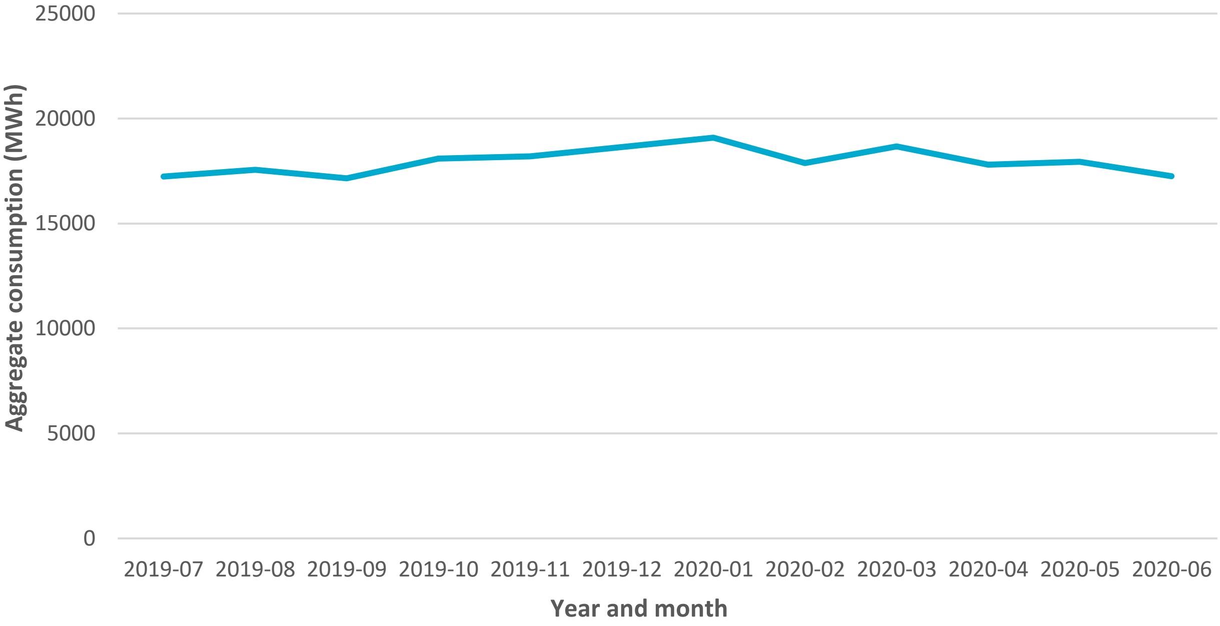

Figure 6 Aggregate monthly energy consumption for a group of small data centres in the financial year 2019-20

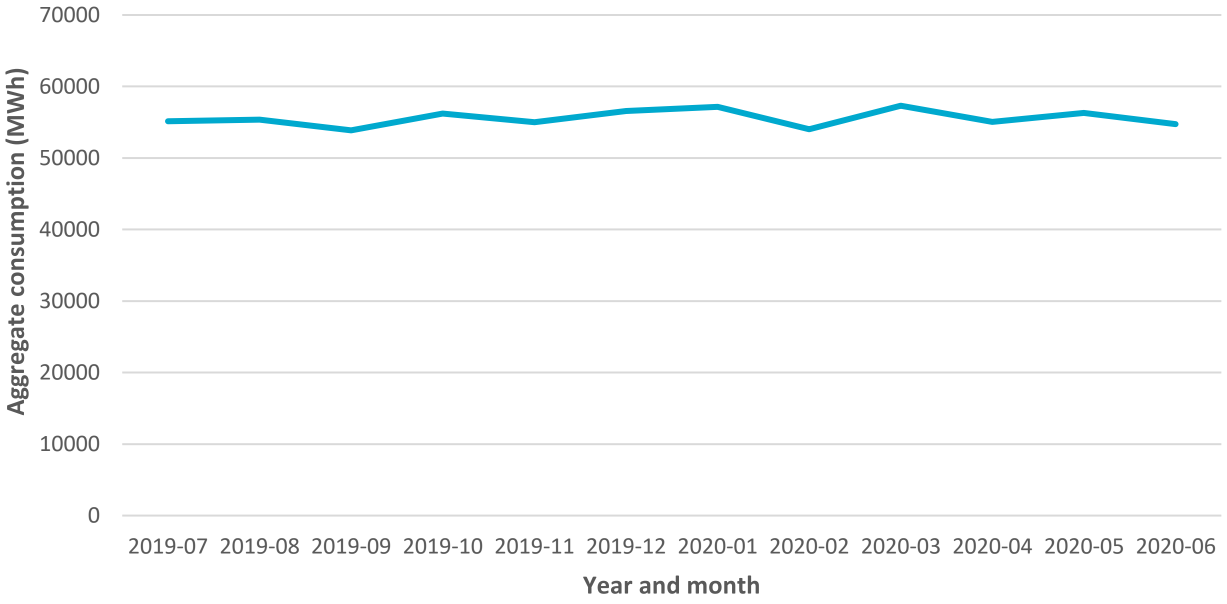

Figure 7 Aggregate monthly energy consumption for a group of large data centres in financial year 19/20

AEMO’s meter data provides an opportunity to examine both the monthly or yearly consumption for data centres and the data centre load over the course of the day. Figure 8 and Figure 9 show the aggregate daily profiles for the same groups of data centres described in the previous figures, averaged across each hour of the day and grouped by season. In all cases the consumption pattern shows an unsurprising diurnal profile, with a higher load in summer, reduced consumption in winter, and a small increase in consumption during the middle of the day suggesting that load patterns are largely flat with small fluctuations that may reflect changes in cooling requirements during warmer parts of the day and year, and patterns of daily workload and building occupancy.

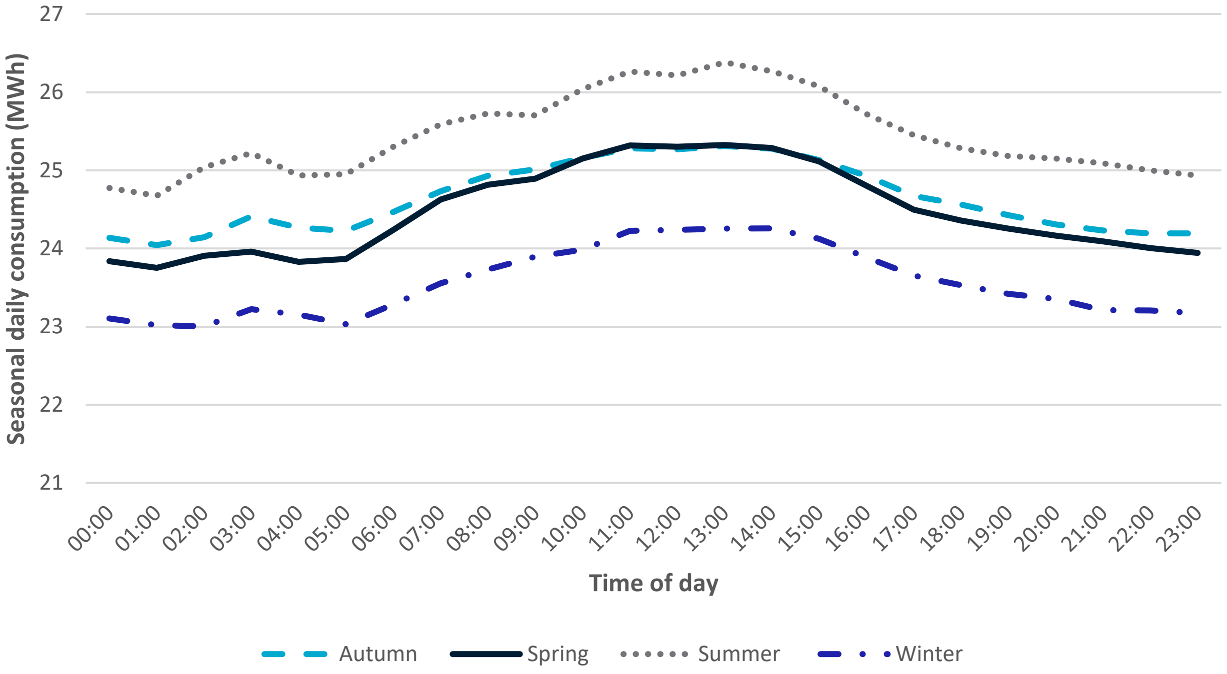

Figure 8 Seasonal daily energy consumption for a group of small data centres in financial year 19/20

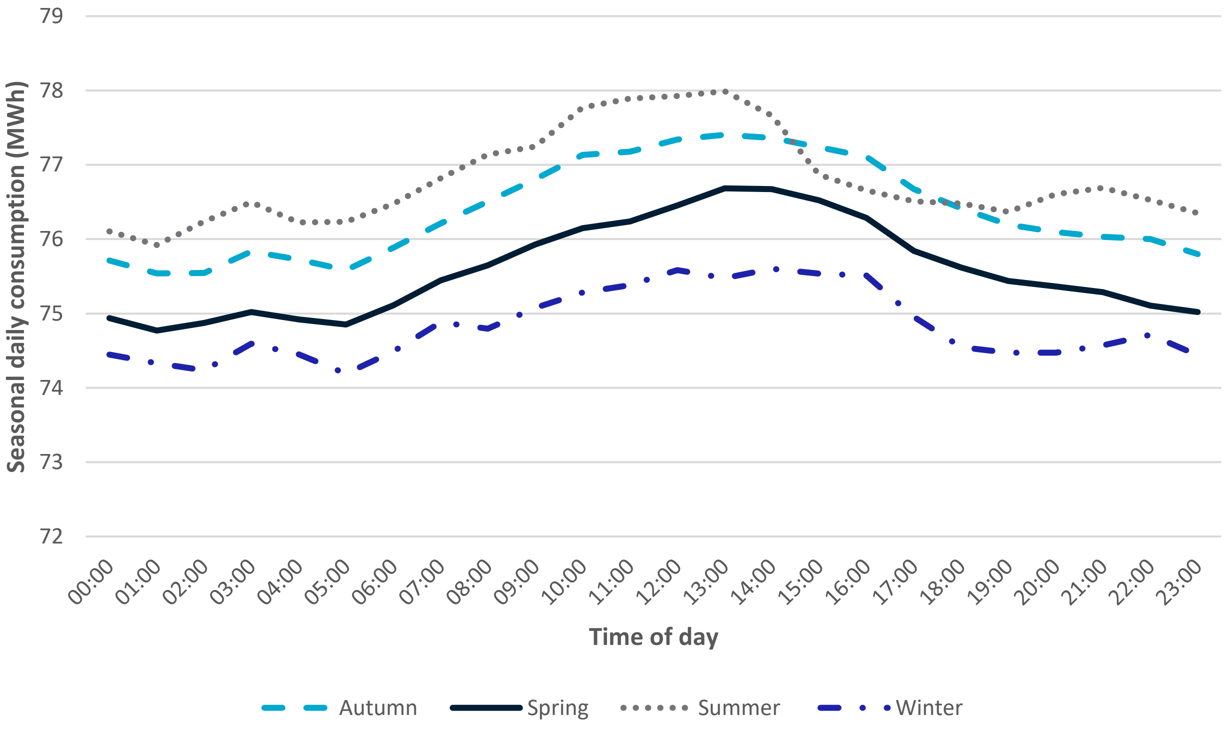

Figure 9 Seasonal daily energy consumption for a group of large data centres in financial year 19/20

Changes over the day and season are, however, quite small compared to the overall load, as seen when the axes are adjusted so the x-axis crosses at zero MWh (Figure 10 and Figure 11). Once again, the data supports the thesis that data centres present a stable and predictable load to the grid.

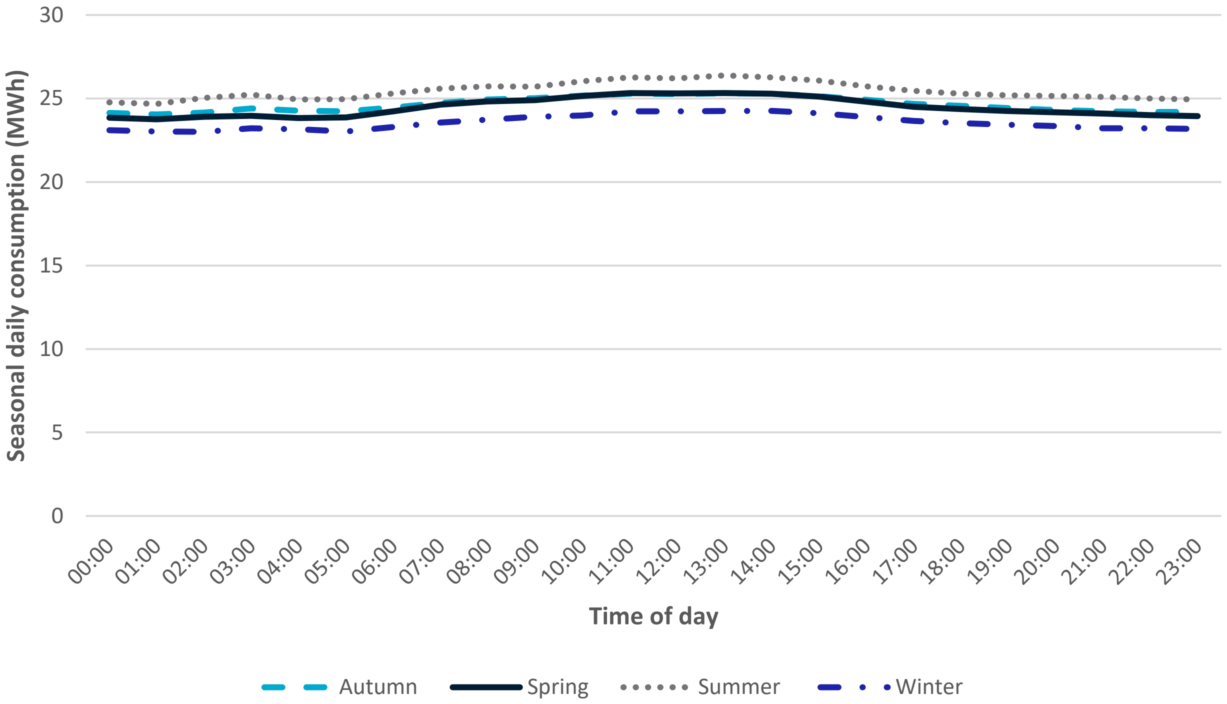

Figure 10 Seasonal daily energy consumption for a group of small data centres in financial year 19/20 with axes adjusted

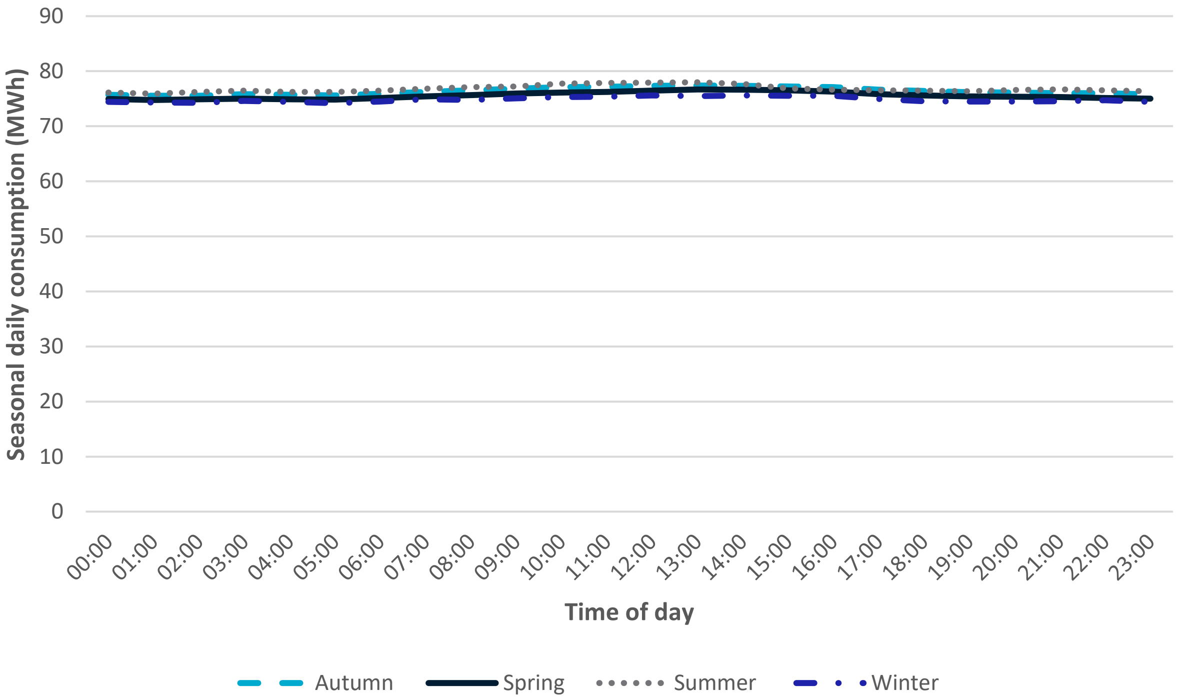

Figure 11 Seasonal daily energy consumption for a group of large data centres in financial year 19/20 with axes adjusted

Like all sources of information about data centres, accessing de-identified consumption data from AEMO includes a set of benefits, limitations and constraints. There are many benefits, including:

1. Detailed data, with half-hourly consumption readings accessible for many Australian data centres.

2. The data captures actual energy consumption rather than the rated capacity of the data centre, which may not reflect the genuine grid impact of the centre on the grid if the planned capacity is not yet utilised or if consumption varies with season (as per the examples described above).
3. The data is historic and therefore presents an opportunity to examine the changing nature of those load profiles over an extended period.
4. Data is captured and provided to AEMO irrespective of research activities or specific regulation programs and therefore does not add any additional overhead to data centre operators.

There are also, however, constraints and limitations:

1. AEMO has legislative and regulatory restrictions on what data it can release; in particular, AEMO cannot release any information that might identify the individuals or entities whose consumption they capture from the meter data. While these restrictions are under active discussion, including in the Energy Security Boards recently released Data Strategy, at the time of writing there are no mechanisms for conducting research on data centres at an individual level using AEMO data outside of AEMO.
2. Even if AEMO could release data for individual data centres, concerns would remain over any commercially sensitive information that might be included in the meter data stream of individual data centres.
3. Data aggregated across multiple meters loses some of the detail that may be useful to understand fully the group in question. For example, at the time of writing we did not have measures that describe the distribution of values in the aggregates we received, limiting our ability to describe any nuances in the makeup of the consumption data that was aggregated (outliers, for example).
4. The methodology described here relies on being able to find and link multiple sources of information. Specifically, we need to identify the addresses of data centres and have AEMO link those addresses to meters. This process is imprecise for multiple reasons:
    a. there isn't a single source for the location of all Australia's commercial data centres
    b. when a data centre can be identified, the address information can be unstructured and/or ambiguous (multiple addresses for a single site, multiple entities at a single address, inconsistent representations of addresses, for example 'st.' vs 'street')
    c. the resulting address may not correspond with one that can be linked to a meter.

On balance, however, we consider the use of de-identified, aggregate load data from AEMO as the best opportunity to examine in depth the actual impact of data centres on Australia's energy network, an opportunity that should be explored in more detail in the future.

Independently of the efforts conducted as part of the NEAR Program, AEMO has also attempted to monitor the growth of the data centre sector over the last few years using reports of new connections for sites greater than 5MW. New South Wales has been the primary focus as the region with the most reported growth in capacity, and AEMO has observed that for the data centres they are aware of in NSW, there appears to be a doubling of capacity from 80MW to 160MW from mid-2017 to the time of writing.

5 The future of Australian data centre energy consumption

While there is little debate about the inexorable growth in computing demand, data storage requirements and internet traffic, projections for the ongoing energy requirement for the sector are less definite. There is uncertainty about the current size of the market, and there are divergent estimates for the ongoing growth of the sector.

5.1 Current size of Australian data centres

As discussed in Section 4.1, there is little publicly available data to describe the current state of energy consumption in the Australian data centre sector. Even if the scope is restricted to providers of colocation services, reliable figures in the public domain are difficult to obtain. Estimates need to be based on reports of maximum capacity rather than actual consumption – as per services such as Cloudscene – or on reports of revenue (for example, Frost & Sullivan, 2018; ReportLinker, 2020).

We consider these figures neither broad enough to cover the entirety of Australia's data centre ecosystem nor sufficiently detailed to provide an estimate of the aggregate energy consumption of Australia's data centres. One of the key recommendations of this report is that AEMO data be fully leveraged to aid in understanding the actual energy consumption of Australian data centres. This will allow the development of reliable, effective baselines against which future growth can be forecast and monitored.

5.2 Rate of sector growth

There is some debate in the literature regarding the trajectory of data centre energy consumption, and there are divergent estimates about the potential impact of ongoing growth in the sector. Uncertainty concerning expectations for growth in the sector can be attributed to:

- the scarcity of data available for research and policy development that describes the actual energy consumption of data centres and how that consumption has changed.
- countervailing trends in the sector (Masanet, et al., 2020). Growing numbers of increasingly large data centres may be responsible for significant growth in energy demand, however that demand may be offset by the improved efficiency of more modern infrastructure and the movement of compute loads from inefficient small data centres to more efficient cloud providers. Shehabi et al. (2016), for example, estimated that if 80% of the data held in small data centres in the U.S. moved to hyperscale facilities, there would be a 25% reduction in energy use.
- technological disruption adding a layer of uncertainty to projections of future energy use. Development of cryptocurrencies such as Bitcoin present an example of a technological

disruption that is difficult to forecast but has significant ongoing energy consumption implications[11].

- non-technological disruptions that are equally difficult to forecast, for example, the effects of COVID restrictions as described above, during which there was estimated to be a significant increase in internet traffic because of such activities as an increased number of people using video conferencing for work, educational and recreational purposes.

The range of estimates that are reported in the literature reflect this uncertainty. Widely cited accounts of forecasts for data centre energy consumption include:

- Andrae and Edler (2015) modelled a range of energy consumption scenarios for the ICT sector that included projections for ongoing data centre energy consumption. Forecasts for the data centre sector were based on projections of growth in internet traffic by Cisco, estimates of electricity consumption ‘per traffic unit’ (per exabyte) and factors accounting for expected energy efficiency increases in the sector. Their modelling projects a range of outcomes, with data centres predicted to account for 3-13% of global energy consumption by 2030. This figure is the basis for much of the public reporting on the growing risk of data centre energy consumption (for example, Jones, 2018).
- Andrae (2020) revised these estimates downwards, with an updated ‘expected’ case projecting data centres using one third as much energy as previously forecast. The updated forecast was a function of a doubling of the expected year-to-year energy efficiency gains per unit of internet traffic, showing the significant sensitivity of forecasts to the factors used to account for increases in energy efficiency.
- Alternatively, Masanet et al. (2020) project that – given current trends in hardware improvements and a continued movement to the cloud from inefficient, smaller data centres – the sector can continue to offset the energy consumption resulting from rapid growth in the number of ‘computing instances’ that will occur over the next three to four years. The modelling in this report uses a ‘bottom-up’ methodology, using, for example, details about changes in server efficiency improvements to inform the projections.

There are jurisdiction-specific forecasts that may be illustrative for Australia. For example, the European Union forecast that growth in data centre energy consumption in the EU will outpace gains in energy efficiency and result in a 21% growth in data centre sector energy consumption by 2025 (Environment Agency Austria & Borderstep Institute, 2020).

Differences in projections about future data centre consumption not only reflect the difficulties described above concerning data availability and the challenge of gauging the impact of behaviour changes, technological disruption and difficult to forecast events like pandemics, they reflect differences in methodology that result from a context where there is little hard data available that accurately describes what is happening in the sector. The large downward revision by Andrae

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[11] The ‘proof-of-work’ calculations that underpin Bitcoin transactions are energy intensive; the party ‘mining’ the currency is required to show that an ever-increasing amount of energy consuming computing cycles have been performed. Krause and Tolaymat (2018) calculated it takes up to 17 megajoules (MJ) of computer power to generate US$1 in Bitcoin, even before factoring in all aspects of the production such as cooling. This is relatively more electricity than it takes to mine gold (5MJ/US$1) and platinum (7MJ/US$1). The Cambridge Bitcoin Electricity Consumption Index (https://cbeci.org), which provides a real-time estimate of total electricity load and consumption of the Bitcoin network, shows that the consumption of electricity by Blockchain mining has steadily increased over the last six years (to the point of being equivalent to that of some small countries), while the efficiency of the mining equipment used has linearly declined.

(2020) shows the sensitivity of modelling to coarse estimates of, in this case, sector-wide energy efficiency gains, and underlines the need for reliable and comprehensive data sources.

While there are differences reported in the expected trajectory of data centre energy consumption, there is a consensus around the need to monitor the impact of the data centre sector closely (Andrae, 2020; Masanet, et al. 2020; Environment Agency Austria & Borderstep Institute, 2020). Even if the most optimistic, short-term estimates of energy sector impact by data centres are accepted, with an expectation that increases in computational workload can continue to be offset by efficiency improvements in hardware and market movements towards more efficient platforms, without accurate data it will be difficult to understand which of the scenarios has actually eventuated and at what point in the future any changes in the profile of data centre energy consumption will require policy interventions or other mediations.

6 Conclusions and recommendations

A review of the literature concerning data centres highlights the uncertainty surrounding this subject: uncertainty in estimates of how much energy is currently consumed by data centres, uncertainty concerning the extent that any current trends can be maintained, and wide-ranging estimates of future energy consumption. Decision making concerning data centres is not well served by existing objective measures of actual data centre energy consumption, and differences in methodologies, assumptions and data sources have resulted in a wide range of divergent projections for the future impact of the sector.

Publicly available data also poorly serves the Australian context. The data provided by AEMO that is outlined in this report, however, provides a glimpse of the significant potential of using meter data for research and policy development in this sector. Appropriately utilised, it would be possible to gather year-on-year energy consumption figures for groups of known data centres and, combined with estimates of near term market growth, projections for energy use in the colocation and cloud computing sectors could be developed with some confidence. This would provide policymakers with a much more solid grounding for deliberations on the relative impact of the sector on the Australian energy system and the value of mandatory reporting or energy efficiency programs and standards, and would provide a foundation for longer term projections and modelling.

Based on our review of the literature, the sector, and publicly available data, we make the following specific recommendations:

- AEMO data should be leveraged to answer specific questions about the current state of the sector and its recent trajectory. This will provide a foundation for an accurate and reliable baseline that can quantify the growth of the sector and its localised impact on specific areas of the grid. This could be at an aggregate level through a program like NEAR, or AEMO could be provided with resourcing to complete this activity internally.
- Activities that promote greater discussion and knowledge sharing between data centre operators, energy network businesses, the energy market operator, government policy teams and the research community should be pursued and formalised. An industry forum of relevant participants with terms of reference for discussions concerning planned growth in the sector, the value and need of energy efficiency programs and initiatives, grid capacity planning and grid connection requirements would be one way of achieving this goal. The output of such a forum could provide a scaffold that summarises the current size of the sector, the rate of change, emerging issues in energy supply (connectivity, sizing, locations), emerging policy questions, case-studies of industry efforts to integrate energy efficiency, renewable generation sources and related initiatives.
- Other jurisdictions are examining strategies for ameliorating the impact of ICT generally and data centres specifically regarding the energy sector and greenhouse gas emissions. We do not provide policy recommendations in this report, however, based on the review of the literature and data sources we recommend that future policy development, whether it concerns energy efficiency policies or standards to promote more effective utilisation of computing resources,

changes in procurement guidelines to encourage the use of more efficient cloud platforms or other strategies to reduce the impact of data centres on the grid should be accompanied by appropriate data collection strategies to ensure the impact of the intervention can be adequately measured and assessed.

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1300 363 400
+61 3 9545 2176
csiroenquiries@csiro.au
www.csiro.au

For further information

Energy Systems
Stephen Lindsay
+61 02 4960 6104
Stephen.Lindsay@csiro.au
csiro.au/energy