Best practice methodologies to reduce the environmental impact of Telecommunication and Data Centre equipment

Drew Bennett

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Report by Drew Bennett
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The International Specialised Skills Institute

1/189 Faraday St,
Carlton VIC 3053
info@issinstitute.org.au
+61 03 9347 4583

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01 Acknowledgements

The Awarding Bodies

The Fellow sincerely thanks The George Alexander Foundation for providing funding support for the ISS Institute and for this Fellowship.

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The George Alexander Foundation (GAF) Scholarship Programs form the core of the foundation's work, operating in partnership with major tertiary institutions, while our Fellowships and other Education grants provide other enriching and challenging educational experiences.

George Alexander believed in the notion of 'planting seeds and hoping they grow into pretty big trees'. The programs supported by the Foundation endeavour to support this ideal and as GAF Fellowship recipients go on to contribute to the community, George's legacy and spirit lives on through their achievements.

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02

Executive Summary

Despite increasing consumer demands for sustainability, Australia has exhibited a sluggish uptake in integrating these practices, slowing our progress towards achieving net-zero emissions targets. The research aims to identify gaps in Australian practices regarding sustainability within the Telecommunication and Data Centre sector as one way to help correct this trend.

Research indicates that Telecommunication Exchanges and Data Centres rank among Australia's largest electricity consumers, collectively consuming 7.1 GWh annually[1]. This amount is bound to increase greatly over the coming years especially with the rapid uptake of Artificial Intelligence (AI) throughout a variety of industries. AI processing in this context is usually performed in Data Centres on equipment that use vast amounts of energy to power the mathematical computation needed for these processes.

The Fellowship aims to explore methodologies focused on reducing the environmental footprint of both Telecommunication Exchange and Data Centre equipment, as well as office equipment. The research proposal seeks to investigate best practices in achieving these objectives through interviewing companies in the United States as world leaders in these areas.

The rationale behind selecting this Fellowship and research topic stems from the Fellows professional background as a Network Engineer at Telstra. At Telstra, the Fellow actively participates in monitoring power consumption within Exchanges and frequently takes the lead in tasks such as removing, replacing, and upgrading various devices. These hands-on experiences have provided them with valuable insights into Telstra's endeavors to reduce energy usage and improve overall efficiency.

By examining overseas practices in the United States, the Fellowship aims to glean valuable insights to inform the implementation of innovative approaches within Australia, accelerating the transition towards a more environmentally sustainable economy. This Fellowship presents an opportune platform to investigate and address the sustainability challenges inherent in the Telecommunication sector, fostering a pathway towards greater environmental responsibility and ultimately reduced emissions.

1 Energy Council of Australia. (2023). Data centres: a 24hr power source. Retrieved from https://www.energycouncil.com.au/analysis/data-centres-a-24hr-power-source/

Objective:

The research focuses on the United States (US), which is renowned as a global leader in the design and development of electronic products. This selection was made based on the country's prominent position at the forefront of innovative practices within the industry and its ability to trial a range of activities due to its economy of scale. Compared to Australia, the United States has many more large businesses that require significant amounts of power to operate and support their large customer base. These businesses have more resources to conduct research and development that Australia simply cannot match due to its size.

Key findings:

The initiatives for power saving in Data Centres and office buildings are aligned with the overarching mission of promoting sustainability and environmental responsibility in construction and operation.

In **Data Centres** power saving, initiatives are categorised into various tiers (each with increasing complexity/expense).

- Easy to implement measures include optimising HVAC systems and regularly upgrading equipment to improve efficiency.
- Other strategies with the potential for a larger impact include implementing energy management systems and optimising cooling schedules to utilise renewable energy sources efficiently.
- More advanced initiatives encompass transitioning to 48V DC power systems and exploring innovative solutions such as underwater Data Centres for superior energy efficiency.

In terms of power saving in **office buildings**, there are several tiers of strategies that can be implemented to reduce energy consumption and improve efficiency.

- These measures include simple actions like turning off networks and Wi-Fi during non-operational hours, employing Internet of Things (IoT) controlled systems for automation, and optimising network-connected assets for efficient management.
- Additionally, more substantial investments that can be implemented include dynamic power-down systems and utilising low-voltage city power for building systems to reduce energy losses.

Throughout each of the strategies explored in this report, the focus remains on reducing energy consumption, improving operational efficiency, and minimising environmental impact. By implementing a combination of these strategies, Data Centres and office buildings can contribute to a more environmentally sustainable future while also potentially realising cost savings and operational benefits. This aligns with the broader mission of promoting environmentally responsible practices in Telecommunications construction and operation.

See the Appendix section for a summary of all power saving initiatives listed in this report.

03
Acronyms & Abbreviations

5GIC	Telstra 5G Innovation Centre
ACEEE	American Council for an Energy-Efficient Economy
AC	Alternating Current
AI	Artificial Intelligence
BAS	Building Automation Systems
Compute	(Noun) Computational processing power
CSU	Colorado State University
DoE	Department of Energy
DC	Direct Current
EMS	Energy management system
EV	Electric Vehicle
EC	Electronically commutated (equipment)
GAF	George Alexander Foundation
GBCA	Green Building Council of Australia
GPO	General Power outlet
GWh	Gigawatt-hour (= 1 x 10^9 watt-hours)
HVAC	Heating Ventilation Air Conditioning
IoT	Internet of Things
ISSI	International Specialised Skills Institute
kW	kilowatt (= 1 x 10^3 watts)
kWh	kilowatt-hour (= 1 x 10^3 watt-hours)
LEED	Leadership in Energy and Environmental Design
LED	Light emitting diode
NRDC	Natural Resources Defense Council
PDU	Power distribution unit
PuE	Power Usage Effectiveness
PoE	Power over Ethernet
USBC	U.S. Green Building Council
UPS	Uninterrupted Power Supply
US	United States
V	Volt (unit of electric potential)
W	Watt (unit of power)

04 Findings

During the Fellowship, interviews were conducted with numerous industry leaders focusing on sustainability in Data Centres. In face-to-face discussions, the Fellow delved into various topics, including Telecommunication and Data Centre equipment, as well as office equipment—an often overlooked area in power consumption reduction, despite its significant interconnections with other sectors.

Before their travels, they meticulously researched and interviewed several international companies with operations in Australia, such as Telstra (the country's largest Telco), Infraco (a company managing numerous Exchanges nationwide), and Microsoft. These interviews provided crucial context for their research, allowing them to assess existing practices in Australia and identify potential gaps in initiatives within these sectors. Consequently, they adjusted the scope of their initial research proposal to include the reduction of power consumption in office buildings alongside Data Centres and Telecommunication Exchanges. Many of the strategies for conserving power explored in their research are applicable to both realms, and when integrated, they can yield even greater energy savings.

The findings have been structured as follows:

A. Current Australia based research
B. International developments
C. Recommendations and analysis of various power saving strategies

A. Current Australia based research

Telstra is currently trialling two new innovative solutions to assist with achieving its sustainability commitments. One of these is using hydrogen fuel cells instead of diesel generators[2]. The second innovative solution is using liquid cooling inside of servers in an Exchange[3], known as water-cooled equipment[4].

Discussions with Infraco revealed that the industry knows what it needs to do to reduce power but sometimes finds it difficult to know where to start. One example of a generally accepted principle for reducing power is converting power systems to 48V DC. Nationally and internationally, different power levels are used to power equipment. For example, Australia has 240V AC, the United States has 125V AC, some equipment from manufacturers are 12V DC, and some are 100V DC. There have

2 Victorian Government. (2023). Renewable energy powering mobile network resilience. Retrieved from https://www.premier.vic.gov.au/renewable-energy-powering-mobile-network-resilience

3 Ericsson. (2024). Ericsson and Telstra boost 5G core efficiency with AMD microprocessors. Retrieved from https://www.ericsson.com/en/press-releases/7/2024/ericsson-and-telstra-boost-5g-core-efficiency-with-amd-microprocessors

4 Tnews. (2014). Hewlett-Packard enters the supercomputer game. Retrieved from https://www.itnews.com.au/news/hewlett-packard-enters-the-supercomputer-game-387859

been numerous studies showing that 48V DC is the most efficient and has the greatest application internationally[5].

Another strategy that is increasingly being implemented in industry in Australia is the use of hot and cold aisles in Exchanges in order to improve cooling efficiency. An extra consideration that could improve the effectiveness of this strategy is that of right sizing the aisle for the total amount of equipment needing to be cooled. Some businesses have the potential to cool a lot more than the equipment inside of the Exchange, therefore without right sizing the aisle they are overcooling the equipment and wasting power. This relates to a third and fourth strategy currently used in Australia of right sizing the power backup (UPS) as well as using lithium-ion batteries rather than lead-acid batteries. Lithium-ion is more efficient and better for the environment than the lead-acid equivalent, so while businesses are upgrading from lead-acid to lithium-ion, this provides a good opportunity to also right-size their UPS for current and future power needs.

B. International developments

Cisco, a prominent developer of network equipment widely utilised in Data Centres and Exchanges worldwide, played a pivotal role in the Fellow's research. During a visit to their office in San Francisco, they engaged in discussions regarding Cisco's efforts to reduce power consumption across all their operations. While touring their facility, the Fellow observed the implementation of strategies aimed at reducing power usage in office equipment.

Cisco detailed the two primary approaches to reducing power consumption within office spaces. The first involves the utilisation of sensors to track personnel movement within the office, thereby minimising power in areas not currently occupied by staff. These sensors also enable analysis of staff behavior patterns and environmental conditions. For instance, they facilitate identifying unused desks and monitoring air quality, providing early warnings to staff, such as advising them to work from home in case of high levels of smoke from forest fires.

Figure 1: Image of Cisco spaces app on an interactive screen. The wayfinding feature helps staff and guests navigate the office efficiently. The dashboard displays occupancy status, allowing automatic air-conditioning shutdown in unoccupied spaces. It also provides real-time data on overall occupancy levels and air quality using sensors throughout the floor.

5 Monolithic Power Systems. (2024). 48V Solutions for Data Centers. Retrieved from https://www.monolithicpower.com/en/products/power-management/48v-data-center.html

Figure 2: Image of Cisco spaces app on a TV screen. This shows key information at a glance, such as occupancy levels per floor, air quality and Co2 levels throughout the building.

The second method for reducing power consumption involves rethinking the office's power supply. Instead of relying on standard AC power cables throughout the entire floor, Cisco employs Power over Ethernet (PoE) cables to energise various office equipment. This approach offers several advantages. Firstly, as most office devices inherently operate on DC power (such as laptops, phones, and LEDs), the need for AC to DC converters is eliminated, resulting in reduced power loss. Secondly, the adoption of PoE cables eliminates the requirement for a qualified technician to install them throughout the office, thereby contributing to cost savings.

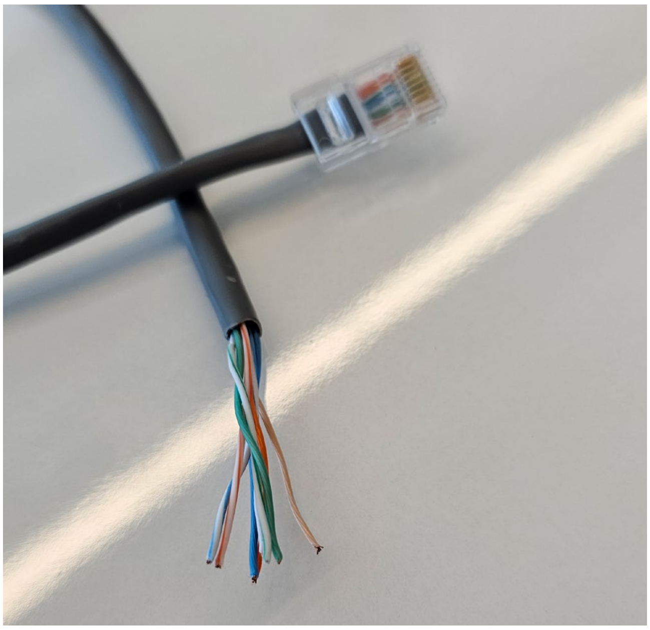
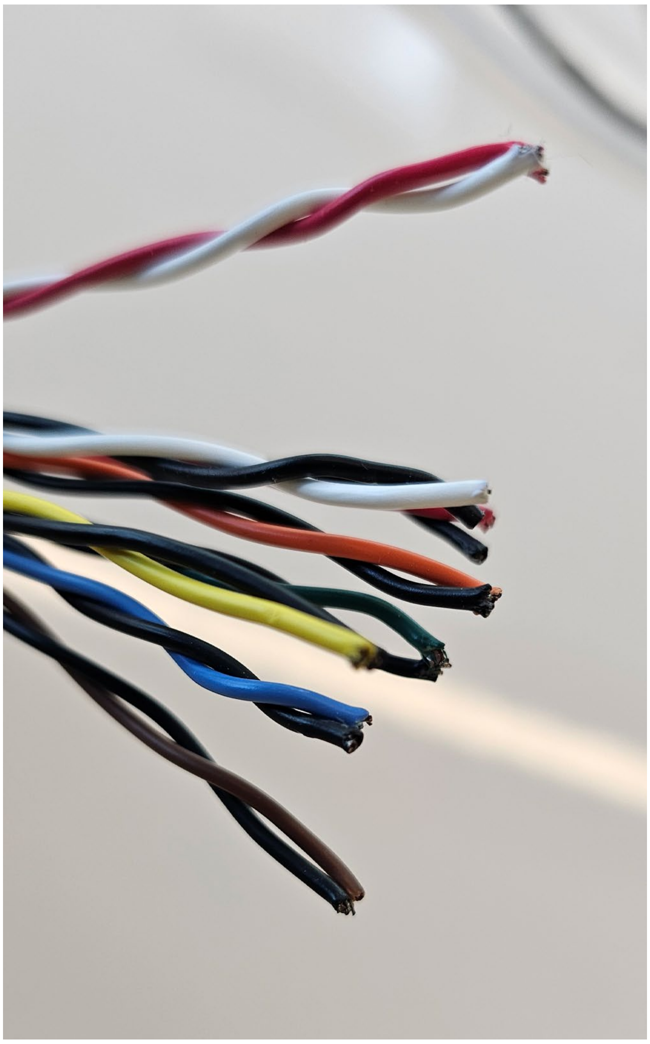


Figure 3 & 4: Image of an existing PoE cable capable of ~25W power delivery



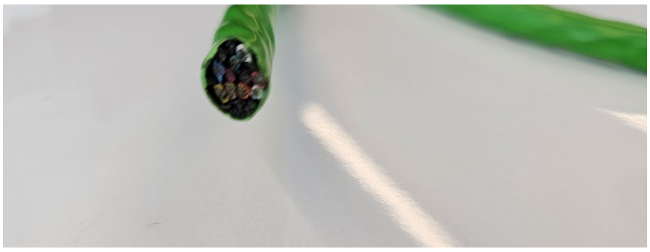


Figure 5, 6 & 7: Image of next generation of PoE capable of up to 90W of power delivery.

In Fort Collins, the Fellow had the opportunity to tour Colorado State University's (CSU) Powerhouse Energy Institute. The laboratory had numerous energy production experiments underway, ranging from 'old' technologies such as wind power to innovative new technologies like hydrogen fuel cells.

Figure 8: Image of a small scale hydrogen generator

Figure 9: Image of counter the CSU Powerhouse has contributed to saving of CO2, this amount is constantly increasing.

Figure 10: Image of the CSU Powerhouse Campus in Fort Collins. The vertical white columns protruding from the brick building are vertical wind turbines. An example of CSUs investigation into various renewable energy sources.

The Fellow was provided a tour of the entire facility, beginning with the early experiments involving hydrogen as an energy source. They were then shown the world's first hydrogen-powered car. Subsequently, they were guided into the laboratory environment, which housed hydrogen fuel creation equipment. These devices facilitate the production of hydrogen and are capable of generating up to 45 kg of hydrogen per day. CSU will need to increase hydrogen production capacity to maximise the renewable energy potential of their recently acquired hydrogen fuel station[6], showcasing the complete hydrogen energy process from creation to utilisation as an energy source. The production of hydrogen holds potential as a substitute for diesel in Exchanges, and a scaled-down version of the fuel station could serve as an equivalent to a diesel generator.

Microsoft is also trialling innovative solutions to reduce power consumption in Data Centres. An example of this is their underwater Data Centre[7] which aims to reduce the cooling needs of the entire Exchange. Exchanges are typically cooled with air conditioners. By putting the Exchange underwater, you can reduce the need for air conditioners as the ocean floor regulates the temperature. Another major trial that Microsoft is conducting, involves the use of hydrogen fuel cells to power Data Centres.[8]

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6 Colorado State University. (2023). Transportation Department awards CSU $8.9M for public hydrogen fueling stations project. Retrieved from https://engr.source.colostate.edu/transportation-department-awards-csu-8-9m-for-publichydrogen-fueling-stations-project

7 Microsoft. (2020). Project Natick: Underwater Datacenter. Retrieved from https://news.microsoft.com/source/features/sustainability/project-natick-underwater-datacenter/

8 Microsoft. (2020). Microsoft's Hydrogen-Powered Datacenters. Retrieved from https://news.microsoft.com/source/features/sustainability/hydrogen-datacenters/

C. Recommendations and analysis of various power saving strategies

While the report explores a range of different strategies, some are easier for businesses to implement than others. The table at Appendix 1 contains a high level summary of all power saving strategies explored through this research. The below section elaborates on these strategies by providing an assessment of the costs and feasibility of implementation to provide a more practical guide for industry. The topics discussed in the following sections are a combination of the Fellow's own experiences in industry and ideas generated through discussions promoted by this research report. The below power saving strategies and analysis (as summarised in Appendix Chart 1 & Table 1) aim to be accessible and therefore easy to implement within industry with the goal of prompting further discussion within industry. Data Centres and Exchange energy efficiency strategies will be explored first, followed by building and office energy supply strategies (noting the many linkages between these topics).

I. Data Centre & Exchange Energy Efficiency Strategies:

a. Basic Measures:

These basic measures collectively contribute to significant energy savings by addressing inefficiencies in equipment operation, optimising building systems, and minimising energy waste.

- **Building Optimisation:** Building optimisation strategies focus on improving the overall energy efficiency of the Data Centre facility itself. This may include upgrading insulation, sealing air leaks, optimising airflow patterns, and installing reflective roofing materials to reduce heat gain. Additionally, incorporating IoT-controlled units for energy monitoring and alarming allows for real-time monitoring and control of energy usage, enabling more efficient operation[9].
- **Lighting Upgrades:** Traditional fluorescent lights consume a significant amount of energy and generate heat, which contributes to cooling loads. Upgrading to energy-efficient LED lighting not only reduces power consumption but also generates less heat, resulting in additional energy savings from reduced cooling requirements[10].
- **Hot/Cold Aisle Isolation:** Hot/cold aisle isolation is a key strategy for optimising airflow within the Data Centre. By implementing measures such as cardboard blocking and blanking panels, hot and cold air streams are kept separate, minimising mixing and reducing the workload on cooling systems. This leads to improved cooling efficiency and reduced energy consumption[11].
- **Equipment Management:** Turning off old or unused equipment when not in use reduces standby power consumption. Additionally, implementing timed or downtime power management strategies for antennas and other devices ensures that power is only supplied when necessary, further reducing energy waste.
- **Rectifier Upgrades:** Rectifiers are responsible for converting alternating current (AC) power to direct current (DC) power for use by Data Centre equipment. Upgrading rectifiers to more efficient models improves the overall energy conversion efficiency, reducing energy losses and decreasing power consumption.
- **HVAC Optimisations:** HVAC systems typically account for a significant portion of a Data Centres' energy consumption. Optimising these systems involves adjusting temperature setpoints, airflow rates, and cooling distribution to match actual server loads. By ensuring that HVAC systems operate efficiently and only provide cooling where necessary, energy consumption can be significantly reduced.

9 Miller, Rich. "Improving Data Center Energy Efficiency through Infrastructure and Layout Optimization." Data Center Knowledge, 2020. https://www.datacenterknowledge.com/design/improving-data-center-energy-efficiency-through-infrastructure-and-layout-optimization

10 Fan, Zhang, et al. "Energy-saving strategies for Data Center lighting." 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). IEEE, 2017. https://ieeexplore.ieee.org/document/8289897

11 "Data Center Air Management." U.S. Department of Energy, 2020. https://www.energy.gov/sites/default/files/2020/04/f74/Data%20Center%20Air%20Management%20-%20Full%20Guide%20v4%200.pdf

- **Fault Fixing and Equipment Upgrades:** Faulty equipment often operates inefficiently, leading to increased energy consumption. Proactively identifying and rectifying equipment faults ensures that systems operate at peak efficiency. Furthermore, upgrading to newer, more energy-efficient technologies, such as servers with higher energy efficiency ratings or more efficient power distribution units (PDUs) can further reduce overall energy consumption.

b. Intermediate Solutions:

These intermediate solutions build upon the basic measures by implementing more advanced technologies and strategies to further optimise energy efficiency and reduce power consumption within the Data Centre environment.

- **Energy Management Systems (EMS):** Energy management systems provide comprehensive monitoring and control of energy usage within the Data Centre[12]. By collecting real-time data on energy consumption from various sources, such as servers, HVAC systems, and lighting, these systems enable operators to identify opportunities for optimisation and implement energy-saving measures proactively[13].
- **Power grid timing (Maximise Green energy):** Once an EMS is installed, a business has the opportunity to not only understand the amount of power they use, but also where it is being used. With further analysis businesses can decide when they need to use their power and if possible prioritise power use during high renewable energy production and minimise power use when this is not the case.

Right sizing equipment:

Cooling Optimisation: Cooling optimisation strategies focus on aligning cooling resources with actual demand to minimise energy consumption. This may involve adjusting cooling schedules to match workload patterns, utilising free cooling methods when ambient temperatures allow, and integrating renewable energy sources, such as solar or wind power, into the cooling infrastructure to reduce reliance on grid power[14].

UPS Optimisation: Uninterruptible power supply (UPS) units provide backup power to critical equipment in the event of a utility power failure. By resizing UPS units to cover only essential equipment, unnecessary power losses associated with over-sizing can be minimised, leading to energy savings and improved efficiency.

EC Fans: Electronically commutated (EC) fans offer improved energy efficiency compared to traditional fan systems. These fans adjust their speed based on cooling demand, resulting in energy savings and reduced operational costs. By replacing older fan systems with EC fans, Data Centres can achieve significant reductions in energy consumption while maintaining adequate cooling capacity[15].

Split System Air Conditioners: Split System Air Conditioners: Split system air conditioners may provide a more efficient cooling solution compared to traditional HVAC systems. By separating the cooling unit into indoor and outdoor components, split systems offer greater flexibility and efficiency in cooling Data Centre environments, resulting in reduced energy consumption and improved thermal management[16].

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12 “Improving Energy Efficiency in Data Centers with Advanced Power Management.” Schneider Electric, 2019. https://www.se.com/ww/en/download/document/SPD_SPD_2.1_EN

13 Microsoft. (2024). Microsoft Sustainability Manager. Retrieved from https://www.microsoft.com/en-us/sustainability/microsoft-sustainability-manager

14 “Energy-Efficient Data Centers: Best Practices Guide.” U.S. Department of Energy, 2019. https://www.energy.gov/sites/default/files/2019/07/f65/Energy-Efficient%20Data%20Centers%20Best%20Practices%20Guide.pdf

15 “Fan Energy Efficiency.” U.S. Department of Energy, 2019. https://www.energy.gov/sites/default/files/2019/07/f65/Fan%20Energy%20Efficiency%20Guide%20v6%200.pdf

16 “Cooling Your Data Center for Maximum Efficiency.” APC by Schneider Electric, 2020. https://www.apc.com/us/en/solutions/business-solutions/data-center-solutions/data-center-design-considerations/cooling-your-data-center.jsp

- **Lithium Batteries:** Lithium batteries offer several advantages over traditional lead-acid batteries, including higher energy density and longer lifespan. By using lithium batteries for UPS and backup power systems, Data Centres can achieve greater energy storage efficiency and reliability, leading to reduced energy consumption and operational costs[17].
- **Liquid-Cooled Servers:** Water-cooled server solutions utilise liquid cooling technology to remove heat from server components more efficiently than air cooling methods. By transferring heat away from server components directly to water, these solutions reduce the need for air conditioning and mechanical cooling systems, resulting in significant energy savings and improved thermal management.
- **Rack Design Improvements:** Rack design improvements, such as blade designs and modular configurations, optimise airflow management and facilitate easier maintenance. By improving airflow within server racks and minimising obstructions, these design enhancements improve cooling efficiency and reduce energy consumption.

c. Advanced and/or more costly approaches:

These advanced approaches represent cutting-edge technologies and strategies that push the boundaries of Data Centre energy efficiency. While they may present technical and logistical challenges, their potential to deliver significant energy savings and operational benefits makes them worthy of consideration for forward-thinking Data Centre operators.

- **Transition to 48V DC:** Transitioning to a 48V DC power distribution system offers several advantages, including improved energy efficiency and reduced power loss compared to traditional AC systems. By converting power distribution to DC at a higher voltage, Data Centres can minimise conversion losses and optimise energy usage, resulting in significant energy savings over time.
- **Building Cooling Strategies:** Building cooling strategies focus on leveraging alternative cooling methods to reduce reliance on mechanical cooling systems. This may involve using outside air for cooling during colder months, implementing evaporative cooling systems, or integrating thermal storage solutions to shift cooling load to off-peak hours. By minimising the use of air conditioning and mechanical cooling systems, Data Centres can reduce energy consumption and operational costs[18].
- **Economy Cycle Cooling:** Economy cycle cooling systems utilise a combination of mechanical and natural cooling methods to optimise energy usage. These systems adjust cooling capacity based on ambient conditions, allowing Data Centres to take advantage of free cooling opportunities when outdoor temperatures are conducive to efficient cooling. By dynamically adjusting cooling capacity to match workload and environmental conditions, economy cycle cooling systems can achieve significant energy savings compared to traditional cooling methods[19].
- **Aisle-Level Water Cooling:** Aisle-level water cooling solutions involve the use of water-cooled infrastructure to remove heat directly from server components at the aisle level. By circulating chilled water through heat exchangers located within server racks or aisles, these solutions provide efficient cooling while minimising the need for traditional air conditioning systems. By reducing reliance on air cooling methods, aisle-level water cooling solutions can achieve significant energy savings and improve thermal management within the Data Centre environment.

17 "Lithium Batteries: The Smart Solution for UPS Systems." Eaton, 2019. https://www.eaton.com/content/dam/eaton/company/news-insights/case-studies/documents/data-center-liquid-cooling-ds-rackspace-case-study-en.pdf

18 "Economizer Modes of Data Center Cooling Systems." U.S. Department of Energy, 2019. https://www.energy.gov/sites/default/files/2019/07/f65/Economizer%20Modes%20of%20Data%20Center%20Cooling%20Systems%20Guide%20v5%200.pdf

19 "Economizer Modes of Data Center Cooling Systems." U.S. Department of Energy, 2019. https://www.energy.gov/sites/default/files/2019/07/f65/Economizer%20Modes%20of%20Data%20Center%20Cooling%20Systems%20Guide%20v5%200.pdf

- **Data Centre Footprint Reduction:** Data Centre footprint reduction strategies focus on consolidating hardware and optimising layout to minimise physical space requirements. This may involve deploying higher-density server racks, virtualizing infrastructure to reduce the number of physical servers, or adopting modular Data Centre designs that allow for scalable expansion. By reducing the physical footprint of the Data Centre, operators can minimise energy consumption associated with lighting, cooling, and other facility operations.
- **Hydrogen fuel cells:** Integrating hydrogen fuel cells as a backup power source for Data Centres is a sustainable practice that presents both advantages and challenges. On the one hand, hydrogen fuel cells offer the potential for clean energy generation, emitting only water vapor as a byproduct, thus reducing greenhouse gas emissions and contributing to environmental sustainability. Moreover, hydrogen can be produced from renewable energy sources such as wind or solar power, further enhancing the sustainability profile of fuel cell systems[20].

Figure 11: Image of a 20kW Hydrogen generator at Colorado State University's Powerhouse Campus in Fort Collins. This could produce ~45kg hydrogen per day.

However, there are several considerations to weigh up when evaluating the sustainability of hydrogen fuel cells for Data Centre backup power. One concern is the current carbon footprint associated with hydrogen production, particularly if derived from fossil fuels, which may undermine the environmental benefits[21]. Additionally, the infrastructure required for hydrogen storage, distribution, and refueling can be costly and may pose safety challenges, particularly in densely populated areas[22].Furthermore, the efficiency of hydrogen fuel cells compared to traditional battery-based backup systems may vary depending on factors such as system design and operational conditions, warranting careful analysis to maximise sustainability benefits[23].

Underwater Data Centres: Underwater Data Centres represent an innovative approach to Data Centre design that leverages the natural cooling properties of water bodies to reduce energy consumption. By submerging server infrastructure in water, these Data Centres can achieve remarkable improvements in energy efficiency and cooling effectiveness compared to traditional land-based facilities. With water providing natural cooling and heat dissipation, underwater Data Centres can achieve lower Power Usage Effectiveness (PuE) metrics and significantly reduce overall energy consumption. There are some drawbacks when it comes to hosting infrastructure in such a unique location, namely maintenance of the equipment inside of the structure. This can be extremely costly as the entire Data Centre will need to be removed from the ocean floor, in order to gain access to the equipment.

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20 Cortés, I., Andrés-Alonso, E., Villanueva-Benito, J.L. (2023). Integrating hydrogen fuel cells as a backup power source for Data Centers: A systematic literature review. Sustainable Computing: Informatics and Systems, 35, 100507. Available at: https://www.sciencedirect.com/science/article/abs/pii/S2213138823003508?via%3Dihub (Accessed: April 13, 2024).

21 Li, X., Zhao, F., & Tang, M. (2020). Data Center Energy Efficiency and Sustainability: Perspectives, Research Issues, and Challenges. iScience, 23(2), 100109. Retrieved from https://www.sciencedirect.com/science/article/pii/S258929912030001X

22 Zhang, Y., Zheng, J., & Zhang, J. (2022). A review on renewable energy powered Data Centers: Challenges and opportunities. Sustainable Operations and Computers, 3(1), 100043. Retrieved from https://www.sciencedirect.com/science/article/pii/S2666791622000100

23 Ryu, J., Lee, J., & Min, K. (2020). Efficiency analysis of hydrogen fuel cells for data center backup power. International Journal of Hydrogen Energy, 45(50), 27187-27200.

II. Building / Office Energy Efficiency Strategies

Basic Measures:

- **Automatic shut down of systems when not in use:** For instance, scheduled shutdowns of networks and Wi-Fi during non-operational hours can be seamlessly managed through IoT-controlled systems. This approach not only conserves energy but also reduces unnecessary power consumption during periods of inactivity, contributing to overall energy savings and cost reduction.
- **Implementing Energy-Efficient Lighting:** Research conducted by the U.S. Department of Energy (DOE) has consistently shown that LED lighting is significantly more energy-efficient than traditional incandescent or fluorescent lighting. LEDs consume up to 75% less energy and last 25 times longer than incandescent lighting, leading to substantial energy savings over time[24].
- **Setting Thermostat Controls:** Studies such as those published in the Energy and Buildings journal have demonstrated the effectiveness of programmable thermostats in reducing energy consumption by optimising temperature control based on occupancy schedules. Properly programmed thermostats can lead to energy savings of up to 10% annually[25].
- **Encouraging Employee Awareness:** Research from organisations such as the Lawrence Berkeley National Laboratory has shown that employee engagement and awareness programs can have a significant impact on energy savings in office buildings. By fostering a culture of energy conservation and encouraging behavioural changes, energy consumption can be reduced by as much as 20%[26].

Intermediate Solutions:

Exploring intermediate solutions entails delving deeper into the integration of network-connected assets to optimise management efficiency and resource utilisation.

- **Leverage IoT:** By leveraging IoT technology and network connectivity, office spaces can be more intelligently managed, allowing for better monitoring and control of energy usage. Systems such as Cisco Spaces offer a way to monitor people count and behaviour in real time, enabling businesses to power down any systems that aren't needed at a moment's notice. This integration enables proactive management of resources, such as lighting, heating, and cooling systems, to ensure optimal energy efficiency while maintaining occupant comfort and productivity.

Figure 12: Image of a Cisco smart sensor measuring Co2, vaping smoke, and other air quality metrics

- **Upgrading HVAC Systems:** Studies conducted by the American Council for an Energy-Efficient Economy (ACEEE) have consistently found that upgrading HVAC systems to more energy-efficient models can lead to substantial energy savings. For example, replacing older, inefficient HVAC units with high-efficiency models can result in energy savings of up to 30%[27].

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24 U.S. Department of Energy. (2024). LED Lighting. Retrieved from https://www.energy.gov/energysaver/led-lighting

25 Habib, K., Parady, B., Al-Hallaj, S., & Jassim, H. (2020). A review on Data Center cooling technology, operating conditions and the corresponding low-grade waste heat recovery opportunities. Energy Conversion and Management, 211, 112749. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S037877881932897X

26 Urgaonkar, R., Pacifici, G., Shenoy, P., & Spreitzer, M. (2016). Toward Sustainable Data Centers: A Review of Power Management Systems. University of California. Retrieved from https://escholarship.org/content/qt0dq0x4tg/qt0dq0x4tg.pdf?t=p8gzv3

27 ACEEE. (2021). Report: Deep Retrofits Can Halve Homes' Energy Use and Emissions. Retrieved from https://www.aceee.org/press-release/2021/12/report-deep-retrofits-can-halve-homes-energy-use-and-emissions

- **Improving Insulation:** Research published in the Journal of Sustainable Cities and Society has demonstrated the effectiveness of improving building insulation in reducing energy consumption. Proper insulation can significantly decrease heat loss during colder months, leading to energy savings of up to 20% in heating costs[28].
- **Implementing Smart Power Strips:** Studies conducted by the Natural Resources Defense Council (NRDC) have shown that smart power strips can effectively reduce energy waste caused by phantom loads. Smart power strips cut power to devices when in standby mode or not in use, resulting in energy savings of up to 10%[29].

Advanced and Costlier Approaches:

Considering advanced strategies involves exploring sophisticated methodologies to further enhance building energy efficiency, albeit at a higher cost. While these strategies may involve a higher initial investment, the long-term energy savings and operational efficiencies they offer can significantly enhance the sustainability and performance of office buildings.

- **Removing AC power runs / switching to PoE for devices & lighting:** Power over Ethernet (PoE) technology presents an opportunity to streamline wiring infrastructure within buildings. PoE enables the delivery of power and data over a single Ethernet cable, simplifying installation and reducing the need for separate power cables. Using PoE (low-voltage infrastructure) rather than existing AC power for lighting and device power supply will minimise losses from AC power blocks therefore improving building energy efficiency.
- **Integrating Building Automation Systems (BAS):** BAS can dynamically adjust HVAC and lighting systems based on occupancy and environmental conditions, leading to energy savings of up to 30% compared to conventional systems.
- **Incorporating Renewable Energy Sources:** Numerous studies have demonstrated the feasibility and benefits of integrating renewable energy sources into commercial buildings. Solar panels and wind turbines can generate clean, renewable energy onsite, reducing reliance on fossil fuels and lowering carbon emissions.
- **Implementing Green Building Certifications:** Research conducted by organisations such as the Green Building Council of Australia[30] and its international counterparts like the U.S. Green Building Council (USGBC) has shown that green building certifications such as Green Star[31] and LEED (Leadership in Energy and Environmental Design) can significantly improve energy efficiency and sustainability outcomes. Buildings certified under LEED have been found to consume 25% less energy and emit 34% less carbon dioxide compared to non-certified buildings. These findings underline the importance of adopting green building standards globally to mitigate environmental impact and promote sustainable development.[32]

During their travels, the Fellow encountered examples of advanced energy monitoring, such as live smart boards that provide detailed information on the power consumption of various assets, as well as the power input from the grid and on-site renewable energy sources.

28 Masanet, E., Brown, R., Shehabi, A., Koomey, J., & Nordman, B. (2013). Energy efficiency improvement opportunities for Data Centers. Energy, 60, 362-379. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0196890413006584

29 NRDC. (2022). Energy Vampires: Keep Your Devices from Wasting Energy and Money. Retrieved from https://www.nrdc.org/stories/energy-vampires-keep-your-devices-wasting-energy-and-money

30 GBCA. (2024). Green Building Council Australia. [Online] Available at: https://new.gbca.org.au/

31 Green Building Council of Australia (GBCA). (2024). Exploring Green Star. Retrieved from https://new.gbca.org.au/green-star/exploring-green-star/

32 US Green Building Council. (2024). LEED Credits for Data Centers - New Construction. Retrieved from https://www.usgbc.org/credits?Rating+System=%22Data+centers+-+New+Construction%22

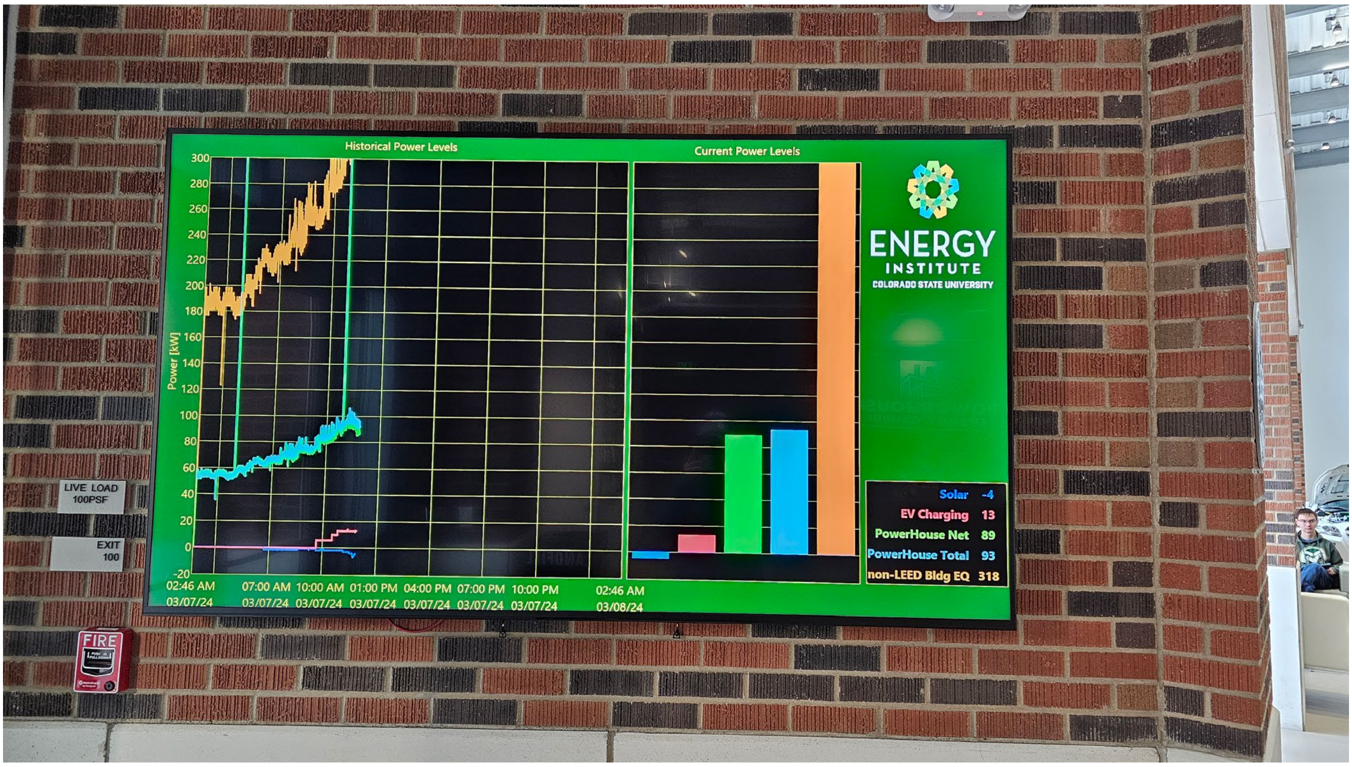

Figure 13: Image of CSUs energy consumption and production metrics, needed to be LEED certified.

D. Future Research Directions:

As technological advancements continue, future research will need to be conducted to verify the validity of these advancements. Some areas that may help the industry to reduce their power consumption in years to come are as follows.

- **Enhanced Component Technologies:** Investigating the potential of upgraded components capable of operating at higher temperatures, thereby reducing the need for extensive cooling infrastructure. This includes advancements in silicon, heat sinks, and soldering techniques to improve efficiency and durability.
- **Power Supply Efficiency:** Exploring avenues to enhance the efficiency of power supplies to meet the increasing demand for compute power while minimising energy consumption. This includes developing more efficient power supply units to mitigate additional strain on city infrastructure.
- **High-Power PoE Solutions:** Considering the adoption of higher power Power over Ethernet (PoE) solutions, particularly for Data Centre racks, to facilitate the deployment of energy-efficient networking equipment and reduce overall power consumption.

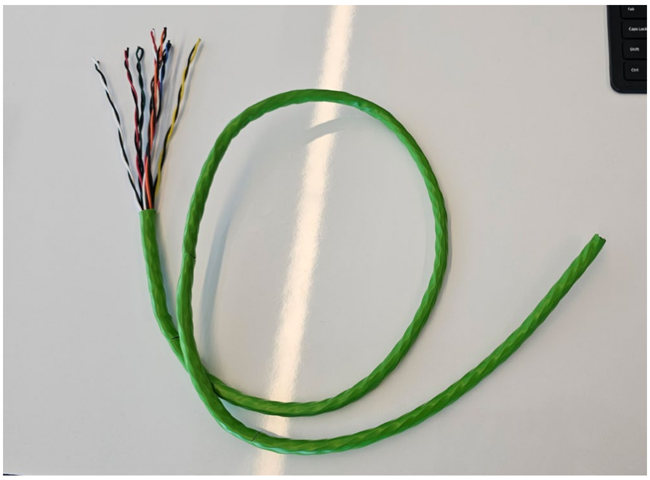

Figure 14: Image of next generation of PoE capable of up to 90W of power delivery.

- **Underwater Data Centres:** Currently there are very few businesses experimenting in this promising field. Investigating the feasibility and benefits of underwater Data Centres can offer promising energy efficiency advantages with a reported Power Usage Effectiveness (PuE) as low as 1.07 which shows the efficiency of the system especially when compared to an already efficient 1.125 of a hot/cold aisle[33]. However, it is essential to address challenges related to equipment robustness and maintenance, as repairs become significantly more challenging once the Data Centre is submerged. Nevertheless, the potential efficiency gains make underwater Data Centres a compelling area for further research and exploration.

- **There is an increasing demand for greater compute power among users:** However, the existing infrastructure provided by city or local governments has limitations in meeting this escalating demand, as evidenced by challenges encountered in supplying power for electric vehicles. Consequently, Data Centres are confronted with the need to explore alternative solutions, such as relocating to different geographical locations or adopting a distributed model across multiple sites, though these approaches may not always be efficient.
- **Hydrogen power (scale up to powering an entire building):** Another potential strategy to mitigate the strain on power resources is for Data Centres to deploy or utilise other (environmentally friendly) hardware, such as large scale hydrogen fuel cells. The use of hydrogen fuel cells does not decrease the power usage of a facility, rather it will source its energy from renewables. Currently the industry is limited by the speed at which hydrogen can be produced. Current hydrogen production methods are insufficient to meet demand of existing Data Centres. To bridge this gap, a blend with Natural Gas can be used, with the goal to lessen the ratio between the two gas sources, until the hardware is run on 100% hydrogen[34].

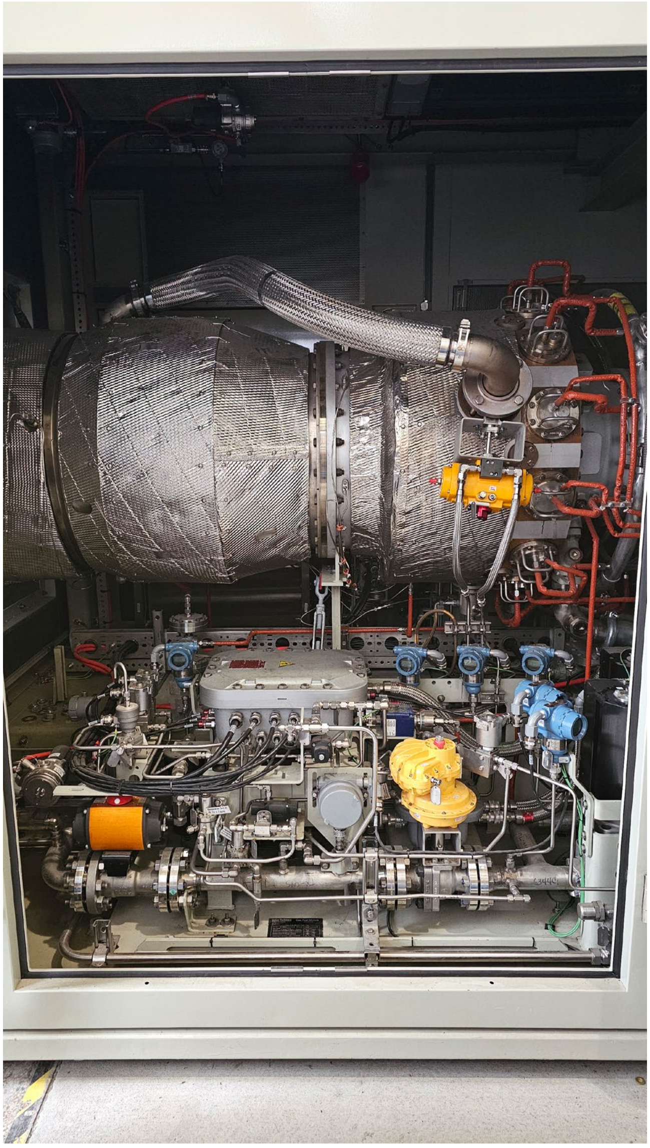

Figure 15: Image of the CSU hydrogen & natural gas generator. It can be used to power the entire campus, with a combination of hydrogen and natural gas.

33 Microsoft. (2018). Putting the cloud under the sea with Ben Cutler. Retrieved from https://www.microsoft.com/en-us/research/podcast/putting-the-cloud-under-the-sea-withben-cutler/
34 Colorado State University. (2022). CSU acquires public hydrogen fuel station, a first for the state of Colorado. Retrieved from https://engr.source.colostate.edu/csu-acquires-public-hydrogen-fuel-station-a-first-for-the-state-of-colorado/

Global Perspectives: Responses to the Topic

Conducting in person meetings provided invaluable opportunities to delve deeper into the nuances of the research topic. These face-to-face discussions allowed for in-depth conversations, exploration of diverse perspectives, and the exchange of ideas that may not have been readily apparent through online research alone. The initial research idea changed direction after these discussions as industry leaders informed the Fellow of the practicalities of certain ideas worth exploring. They also helped in assigning relevant strategies into three tiers, showing what businesses can easily implement compared to what is more challenging and/or costly. This approach ensures that the findings and recommendations are realistic and aligned with practical industry considerations.

In addition to the insights gained through direct interactions, site visits and immersive experiences provided valuable context and real-world examples for the research topic. Observing sustainable practices in action within different international settings offered tangible illustrations of the principles and strategies discussed in the report. These firsthand experiences served to reinforce the importance of practical implementation and highlighted the potential impact of innovative solutions in addressing the research topic.

Moreover, international collaborations forged during these engagements opened doors to potential partnerships, knowledge exchange, and future research opportunities. By establishing connections with stakeholders across borders, avenues for continued dialogue, collaboration, and mutual learning were cultivated, enhancing the research's broader impact and relevance.

Contrasts and Similarities: Insights from Travels compared to the Australian Context

A notable difference observed in the Fellow's travels was the prevalence of sustainability-focused initiatives in certain cities in the United States compared to the industry-centric focus observed in Australia. For instance, a number of new constructions in Denver, Colorado boast LEED certification, indicative of a widespread commitment to sustainable building practices. Additionally, Denver stands out for its considerable investment in hydrogen-focused research, signaling a proactive approach towards exploring alternative energy sources.

Conversely, companies situated in other regions of the United States exhibit a comparatively lesser emphasis on sustainability initiatives. This disparity is partly attributed to the relatively lower cost of fuel in the United States compared to Australia, which diminishes the economic incentives for companies to prioritise sustainable practices. As a result, sustainability efforts may vary significantly depending on geographical location and prevailing economic factors.

05 Considerations and Next Steps

This report examines sustainability challenges and opportunities in Australia's Telecommunication sector, focusing on cultural shifts, internal processes, costs, and regulatory issues. Despite obstacles like funding constraints and research-practice gaps, efforts to disseminate insights and refine industry standards show promise. Enhancing sustainability within Telstra and the wider industry, while addressing supply chain management and industry-specific challenges, is crucial for advancing environmental stewardship and operational efficiency.

Primary Obstacles

Cultural Shifts Towards Sustainability: While awareness regarding power-saving measures and sustainability is prevalent in Australia, there remains a need to prioritise these concerns within organisational cultures. It is imperative to shift the mindset from mere compliance to a deeper understanding of the social benefits, particularly concerning future generations. This necessitates leadership commitment from upper management, such as initiatives led by CEOs from Telstra[35], and Ciscio[36], to embed sustainability practices into the core values of an organisation.

Internal Business Processes: Efforts to reduce power consumption must be embedded within internal business processes, with a top-down approach complemented by feedback mechanisms from all employees. Encouraging active participation by employees, such as on site technicians and their office staff coworkers, fosters a culture of continuous improvement. Moreover, mechanisms for idea sharing, generation and implementation must be established to empower all employees to contribute to power-saving initiatives effectively.

Cost Considerations: One of the primary challenges encountered by businesses during the research and implementation phases revolves around cost constraints. This encompasses not only the initial investment required but also ongoing research expenditure associated with sustainability initiatives.

For instance, the expense associated with retrofitting existing buildings can often outweigh the cost of starting anew making this a less feasible option. Hydrogen fuel cells can also pose significant financial barriers, with costs ranging from 8 to 10 times higher than their diesel counterparts. Additionally, issues related to refuelling infrastructure present further hurdles to widespread adoption.

35 Telstra. (2020). Acting on Climate Change. Retrieved from https://www.telstra.com.au/exchange/acting-on-climate-change
36 CRN. (2023). Cisco CEO: Sustainability has taken on a new level of prioritization. Retrieved from https://www.crn.com/news/networking/cisco-ceo-sustainability-has-taken-on-a-new-levelof-prioritization

Government Regulations and Standards: National, state, and local governments play a crucial role in enforcing standards for new constructions, and advocating for sustainable building practices. Compliance with these regulations ensures that environmental considerations are integrated into urban development plans.

Power demand is increasing faster than ever[37]: As more businesses start using AI in their everyday processes, the infrastructure (compute) that supports these processes will become a greater drain on Data Centres and increase their power use. Despite industry trying to make Data Centres more efficient, the reality is that power demand is increasing even faster than the improvements in efficiency will ever be able to keep up.

Challenges Encountered in Research and Implementation

Complexities of Ongoing Research: The dynamic nature of sustainability research presents ongoing challenges, including the need for continuous investment in research and development to stay abreast of emerging technologies and best practices. This may also present an obstacle to transparency and collaborative knowledge-sharing.

Industry Dynamics and Reporting Biases: The fast-paced nature of the Telecommunications industry poses challenges in accurately documenting research outcomes. Private organisations often hesitate to disclose failures or unsuccessful trials, leading to reporting biases. Conversely, academic research may offer more transparency regarding what does not work, but lacks the scale and practical applicability of private sector initiatives.

Discrepancies Between Research and Real-World Applications: Another challenge lies in the disparity between research-scale experiments and real-world applications. What may demonstrate success in controlled research environments, such as individual servers or racks, may not necessarily translate effectively to operational settings, such as partially filled Exchanges. This necessitates careful consideration of scalability and practicality in implementing research findings.

Initiatives to implement in Australia

Initial plans involve disseminating the research findings to key stakeholders within Telstra and Infraco, including designers and teams engaged in broader sustainability initiatives across both organisations. Additionally, efforts will be directed towards engaging architects responsible for creating guidelines pertaining to equipment deployment and operational practices. This collaborative approach aims to ensure that research insights are effectively integrated into future projects and initiatives within the Australian context.

Future research possibilities

One area of interest involves closely monitoring emerging developments, many of which are still in early or trial phases. Examples include innovations such as underwater Data Centres and advancements in hydrogen energy technology. Additionally, there is a keen interest in exploring the potential applications of PoE for providing both power and connectivity within office spaces and Data Centres where feasible and appropriate. These areas represent promising avenues for future research endeavours, aiming to contribute to the ongoing evolution of sustainable practices within the Telecommunication and Data Centre sectors.

Next steps for the Fellow

Within Telstra, efforts will focus on enhancing LEED certification standards to further uplift sustainability practices. Additionally, the Fellow plans to revise the standard Exchange design criteria used by Telstra, with a particular emphasis on implementing “right sizing” strategies to minimise power consumption. These initiatives aim to drive continuous improvement in sustainability performance both within Telstra and across the Telecommunication sector as a whole.

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37 Popper, B. (2018). Sam Altman says the age of AI will require an energy breakthrough. Popular Science. Retrieved from https://www.popsci.com/technology/sam-altman-age-of-ai-will-require-an-energy-breakthrough/

Factors to consider within the industry

It is essential to prioritise LEED / Green Star certification for all buildings, including Data Centres and Exchanges. Additionally, efforts should be directed towards reducing the Power Usage Effectiveness (PuE) of these facilities. These considerations are crucial for enhancing sustainability performance and minimising environmental impact within the industry.

Potential limitations

Supply Chain Management: Effective supply chain management is crucial to ensure that all stakeholders are engaged in minimising adverse environmental practices. However, challenges may arise in coordinating and enforcing sustainability standards across diverse supply chains.

Out-of-Scope Considerations

There are countless strategies that could be explored as part of the topic due to its broad nature; however, the Fellow chose to focus on those with the most information and evidence available, thereby aiming to have the greatest impact on the industry. Collating all of these ideas in one easy-to-understand report was an important point addressed by the Fellow. Other topics that were not included were:

- Limited Research on Virtualized Hardware:

  The research may have limitations in terms of the depth of investigation into virtualized hardware. While virtualization offers potential energy-saving benefits, the extent of its impact was not extensively explored.

- Industry-Specific Challenges:

  Telecommunications infrastructure may present unique challenges compared to Data Centres, particularly in terms of sizing inaccuracies due to frequent technology updates. Conversely, Data Centres may face challenges associated with static infrastructure and long-term equipment utilisation.

-

- Supply chain sustainability:

  Methodologies to ensure that the equipment itself is sustainably sourced and to enhance the sustainability of the supply chain associated with Telecommunication and Data Centre equipment was not a topic covered in this report but can also be a critical component in reducing the environmental impacts of this sector.

06
Impacts of Fellowship

Personal Impact

The Fellowship has had a significant impact on the Fellow's personal life, primarily by positioning them as a knowledge leader and a key advocate for sustainability initiatives within Telstra and Infraco. They have become a trusted sounding board for sustainability endeavors, fostering collaborations and driving positive change within the organisation. Moreover, the Fellowship has helped them develop extensive internal and external networks, enhancing their communication skills through the experience of 'cold contacting' various organisations to seek information and set up meetings. Additionally, the research aspect of the Fellowship has led to significant improvements in their investigative and analytical skills.

Professional Impact

Professionally, the Fellowship has brought about notable changes within the Fellow's work environment. They have become a recognised knowledge leader within Telstra, connecting different teams and serving as a liaison between various departments. This has resulted in increased collaboration and knowledge sharing, particularly in sustainability-related endeavors. Internally, the Fellowship has prompted Telstra to engage more actively in sustainability discussions, with efforts aimed at uplifting LEED qualifications. Externally, connections between Telstra and organisations such as Cisco have been strengthened, fostering broader sectoral collaboration.

Organisational Impact

The Fellowship has influenced Telstra to strengthen its commitment to sustainability, intensifying discussions around reducing power consumption and adopting sustainable practices. In terms of research from this report, Telstra has already implemented most of the 'easy' Data Centre power saving initiatives and is on its way to trialling and installing the intermediate and advanced solutions in the coming years. Where the gap needs to be filled is in solutions regarding its vast office spaces. Being a national organisation with staff around the country, it will be a huge task to retrofit all office spaces. By using baselines such as LEED certification and new innovative technologies such as PoE cables for powering everyday appliances, making every office sustainable should be a very achievable goal.

Another concrete example of an impact at Telstra is the documentation of power savings initiatives within the 5GIC, demonstrating the feasibility and benefits of implementing sustainable practices across the sector.

Broader Sector Impact

The Fellowship has established a connection between the Telecommunication sector and sustainability findings, with implications extending beyond Telstra to telecommunication competitors and the wider industry. The potential for shared ideas and collaborative efforts underscores the sector's collective responsibility towards sustainability. Given most businesses in the telecommunication and Data Centre sector would have various office spaces to host staff members, retrofitting these buildings and gaining LEED certification status would be a great first step to becoming a more sustainable sector. Experimenting with power saving tools such as network-controlled assets can be a great additional step to rolling out a similar management system into the wider sector. If staff can see the changes around them in their office space, it may encourage them to apply these learning and and utilise them in Data Centres and Exchanges as well. As Australia becomes a more environmentally conscious nation, its energy requirements may increase in the short term (e.g. to support the uptake of electric vehicles) and supply from the grid initially may not be able to match this. Through implementing the learnings in this report, the telecommunication and Data Centre sector can not only decrease their costs, but also 'give back' part of their power allocation to the grid, enabling Australia as a whole to adopt other environmentally friendly strategies such as electric vehicles.

Future Plans

Looking ahead, future plans involve further initiatives within the 5GIC, with a continued focus on reducing power consumption and implementing sustainable methodologies. This includes ongoing measurement and evaluation to track power saving progress and identify areas for improvement. Additionally, there are plans to disseminate the research findings more broadly, potentially influencing policy and methodologies at organisational and sectoral levels.

07
Sector Engagement (Dissemination)

The Fellow aims to disseminate the knowledge acquired through their research using various channels and formats to maximise impact and promote sustainability initiatives.

Firstly, they intend to conduct a series of comprehensive presentations within Telstra, targeting key stakeholders including sustainability teams. These sessions will provide valuable feedback on ongoing initiatives and offer insights from their research to support Telstra's trials. Additionally, they plan to arrange tours of the 5GIC, hosting government officials, industry stakeholders, and school students to showcase practical examples such as energy monitoring dashboards derived from their research findings.

Furthermore, they will extend the dissemination of knowledge to Infraco by advocating for the integration of sustainable practices into their operational standards. This will involve proposing guidelines centered on energy efficiency to reduce overall power consumption.

In parallel, the Fellow aims to engage with local Members of Parliament, including the Minister for Communications, to highlight the significance of adopting sustainable approaches in the design and refurbishment of Data Centres, Telecommunication Exchanges, and office spaces. Emphasising the potential cost savings for businesses through reduced energy bills and aligning with international commitments like the Paris Agreement and Tokyo Statement on Energy Transitions will underscore the benefits of such initiatives.

Throughout the Fellow's travels and interactions, they have been committed to actively sharing and disseminating knowledge gathered before and during their travels. The Fellow created a simplified Appendix: Table 1, and updated through their travels to provide an easy to distribute summary of the research findings.

This comprehensive dissemination strategy aims to leverage collaborative efforts across various sectors to drive sustainable practices and enhance energy efficiency on a broader scale. By sharing insights and best practices, they seek to empower stakeholders, raise awareness, and contribute to meaningful advancements in sustainability within the Telecommunication and Data Centre industries.

08
Conclusion

In conclusion, this research report delves into the intricate landscape of energy efficiency strategies within Data Centres, Telecommunication Exchanges and office spaces, focusing on practical measures to optimise operations and reduce environmental impact. The exploration of power-saving initiatives spans from basic adjustments such as HVAC optimisations and equipment upgrades to advanced solutions like underwater Data Centres and 48V DC transitions.

The study emphasises the importance of implementing sustainable practices to address the growing energy demands of modern infrastructure. Basic measures, including LED lighting upgrades and equipment management strategies, contribute to immediate energy savings and operational efficiency. Intermediate solutions, such as implementing energy management systems and exploring water-cooled servers, demonstrate significant potential for reducing energy consumption and improving overall cooling efficiency.

Furthermore, advanced approaches like economy cycle cooling and transitioning to 48V DC power systems highlight the innovation required to achieve substantial energy efficiency gains. The research underscores the need for continuous technological advancements and policy support to realise the full potential of sustainable energy practices.

In terms of dissemination, the report advocates for widespread knowledge sharing and engagement across various stakeholders, including Telecommunication companies, government agencies, and industry partners. Leveraging insights from international experiences and collaborations, the research promotes the adoption of energy-efficient technologies and practices to drive meaningful progress towards sustainability goals.

Overall, this research report underscores the critical role of energy efficiency in mitigating environmental impact and achieving long-term sustainability in Data Centre and Telecommunication operations. By implementing the strategies outlined in this report and fostering collaborative initiatives, stakeholders can pave the way for a more efficient and sustainable future in the Telecommunication and Data Centre sectors.

09
Appendices

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Quick glance charts of all power saving initiatives

Chart 1: Telecommunication Exchanges and Data Centres

Chart 2: Office spaces

High level overview of strategies to reduce power consumption

Table 1: Telecommunication Exchanges and Data Centres

Table 2: Office spaces

Quick glance chart of all power saving initiatives

Chart 1: Telecommunication Exchanges and Data Centres

				Large redesign needed
				Underwater Data Centres Exploration
				Hydrogen fuel cells
				Data Centre Footprint Reduction
				Whole Rack/Aisle Liquid Cooling
			Retro fit to Building and Equipment	Transitioning to 48V DC
			Economy Cycle Cooling	Economy Cycle Cooling
			Liquid Cooling for Servers	Liquid Cooling for Servers
		Data-driven enhancements	Lithium Batteries	Lithium Batteries
		Power grid timing (Maximise Green energy)	Power grid timing (Maximise Green energy)	Power grid timing (Maximise Green energy)
		Energy Management Systems (EMS) Implementation	Energy Management Systems (EMS) Implementation	Energy Management Systems (EMS) Implementation
		Rack-Mounted Equipment Design Improvements	Rack-Mounted Equipment Design Improvements	Rack-Mounted Equipment Design Improvements
		Battery Backup Resizing	Battery Backup Resizing	Battery Backup Resizing
	General uplift activities	Aisle Redesign	Aisle Redesign	Aisle Redesign
	Cooling Fan Upgrades	Cooling Fan Upgrades	Cooling Fan Upgrades	Cooling Fan Upgrades
	Rectifier upgrades	Rectifier upgrades	Rectifier upgrades	Rectifier upgrades
	Building Optimisation	Building Optimisation	Building Optimisation	Building Optimisation
Minimal cost & effort	Fault Fixing and Equipment Upgrades	Fault Fixing and Equipment Upgrades	Fault Fixing and Equipment Upgrades	Fault Fixing and Equipment Upgrades
HVAC Optimisation	HVAC Optimisation	HVAC Optimisation	HVAC Optimisation	HVAC Optimisation
LED Lighting Installation	LED Lighting Installation	LED Lighting Installation	LED Lighting Installation	LED Lighting Installation
Hot / Cold Aisles Optimisation	Hot / Cold Aisles Optimisation	Hot / Cold Aisles Optimisation	Hot / Cold Aisles Optimisation	Hot / Cold Aisles Optimisation
Power Optimisation	Power Optimisation	Power Optimisation	Power Optimisation	Power Optimisation
Down Power Equipment	Down Power Equipment	Down Power Equipment	Down Power Equipment	Down Power Equipment

Easy ← **Intermediate** → **Advanced**

Chart 2: Office spaces

				Large redesign needed
				LEED / Green Star Building Design
				Efficient Power Distribution
				Insulation Improvements
			Retro fit to Building and Equipment	Power Over Ethernet (PoE) Implementation
			Renewable Energy Incorporation	Renewable Energy Incorporation
		Data-driven enhancements	Building Automation Systems (BAS) Integration	Building Automation Systems (BAS) Integration
	General uplift activities	Smart Building: Network Controlled Assets	Smart Building: Network Controlled Assets	Smart Building: Network Controlled Assets
	HVAC Systems Upgrades	HVAC Systems Upgrades	HVAC Systems Upgrades	HVAC Systems Upgrades
Minimal cost & effort	Smart Power Strips Implementation	Smart Power Strips Implementation	Smart Power Strips Implementation	Smart Power Strips Implementation
Proper Thermostat Control	Proper Thermostat Control	Proper Thermostat Control	Proper Thermostat Control	Proper Thermostat Control
Network Equipment and WiFi Shutdown	Network Equipment and WiFi Shutdown	Network Equipment and WiFi Shutdown	Network Equipment and WiFi Shutdown	Network Equipment and WiFi Shutdown
Energy Efficient lighting (LEDs)	Energy Efficient lighting (LEDs)	Energy Efficient lighting (LEDs)	Energy Efficient lighting (LEDs)	Energy Efficient lighting (LEDs)
Employee awareness and encouragement	Employee awareness and encouragement	Employee awareness and encouragement	Employee awareness and encouragement	Employee awareness and encouragement

Easy **Intermediate** **Advanced**

High level overview of strategies to reduce power consumption

Table 1: Telecommunication Exchanges and Data Centres

Difficulty	Strategy	Action Plan
Telecommunication Exchanges and Data Centres		
Easy	Down Power Equipment	Power off unused equipment. Ideally remove and recycle components.
	Power Optimisation	For equipment in locations that cannot be completely powered off, reduce their power levels when possible (Standby / Low Power Mode)
	Hot / Cold Aisles Optimisation	Utilise blanking panels in unused rack spaces to better separate hot and cold aisles, thereby enhancing energy efficiency.
	LED Lighting Installation	Replace fluorescent lights with LED fixtures.
	HVAC Optimisation	Address faults and upgrade equipment.
	Building Optimisation	Upgrade air conditioning systems and implement IoT-controlled energy monitoring and alarming units.
	Rectifier upgrades	Enhance rectifiers with more efficient models to improve efficiency and minimise AC to DC power conversion losses.
Intermediate	Cooling Fan Upgrades	Replace older belt-driven fans with EC fans for greater efficiency.
	Aisle Redesign	Block off entire unoccupied sections of an aisle to reduce the need for cooling unused areas.
	Battery Backup Resising	Resize battery backups to cover only the general load, and consider switching to lithium-ion batteries instead of lead-acid.
	Rack-Mounted Equipment Design Improvements	Improve rack design for easier maintenance by using a blade design, allowing servers to be easily swapped or maintained. This reduces body heat during maintenance and simplifies cable management.
	Energy Management Systems (EMS) Implementation	Implement tools like Microsoft Sustainability Manager to virtualise and monitor power consumption. Utilise data to optimise cooling times—such as increasing cooling during high renewable energy periods and allowing for a reduction of AC use during peak pricing. EMS also aids in identifying power consumption anomalies for fault detection.
	Liquid Cooling for Servers	Transition from air-cooled to liquid-cooled servers to enhance cooling efficiency for the most heat-intensive components.
Advanced	Economy cycle cooling	Utilise outside cool air during evenings to cool the building, reducing the reliance on air conditioning.
	Transitioning to 48V DC	48V DC powered equipment generally outperforms both 12V DC and 240V AC.
	Whole Rack/Aisle Liquid Cooling	Implement a liquid cooling system for entire racks or aisles.
	Data Centre Footprint Reduction	Consolidate equipment into a centralised location and block off unused areas to minimise wasted cooling.
	Underwater Data Centres Exploration	Although still under investigation, underwater data centres have shown promising results for hardware that doesn't require frequent maintenance.

Table 2: Office Spaces

Difficulty	Strategy	Action Plan
Office Spaces		
Easy	Employee awareness Encouragement	Foster a culture of energy conservation through employee engagement and awareness programs to reduce energy consumption by up to 20%.
	Energy Efficient lighting (LEDs)	Use LED lighting to consume up to 75% less energy and last 25 times longer than incandescent lighting, leading to substantial energy savings over time.
	Network Equipment and WiFi Shutdown	Shut down network and WiFi systems after hours, using IoT controls to automate the process.
	Proper thermostat control	Reduce energy consumption by optimizing temperature control with programmable thermostats based on occupancy schedules to achieve up to 10% annual energy savings.
	Smart power strips implementation	Reduce energy waste caused by phantom loads by using smart power strips to cut power to devices when in standby mode or not in use, resulting in up to 10% energy savings on electricity bills.
	HVAC systems upgrades	Upgrade HVAC systems to more energy-efficient models to achieve substantial energy savings, with potential reductions of up to 30%.
Intermediate	Smart Building: Network controlled assets	Implement AI to monitor and control assets, powering down unused equipment and adjusting building temperatures based on occupancy.
	Building Automation Systems (BAS) Integration	Adjust HVAC and lighting systems dynamically based on occupancy and environmental conditions to achieve energy savings of up to 30%.
	Renewable energy incorporation	Integrate renewable energy sources like solar panels and wind turbines to generate clean, renewable energy onsite, reducing reliance on fossil fuels and lowering carbon emissions.
Advanced	Power Over Ethernet (PoE) Implementation	Convert lighting and other low-power assets to PoE (Power over Ethernet)
	Efficient Power Distribution	Implement an in building low-voltage DC system for internal devices like LED lighting, phone chargers, laptops, and screens to reduce power conversion losses.
	LEED / Green Star Building Design	Adhere to LEED and Green Star standards to create energy-efficient buildings, reducing the overall power consumption.