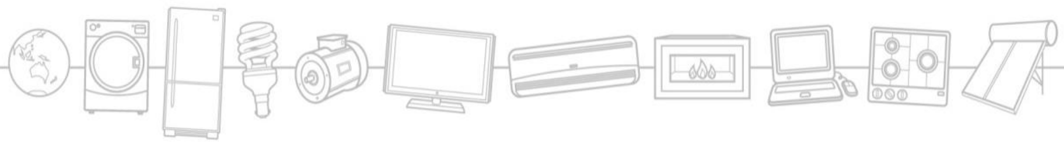
E3
Equipment Energy
Efficiency

Energy Efficiency Policy Options for Australian and New Zealand Data Centres

Final Report

Consumer Research Associates

April 2014



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Executive Summary

This Report was commissioned by the Equipment Energy Efficiency (E3) Program, a joint initiative of the Australian, State and Territory Governments and the New Zealand Government. Its purpose was to investigate and recommend suitable policy options to improve the energy efficiency of data centres in Australia and New Zealand.

The full report includes:

1. Development of the definition of a data centre;
2. Modelled projections of trends in numbers of data centres, their energy consumption and growth;
3. A review of energy efficiency policies applicable to data centres and identification of the challenges to achieving such energy efficiency improvement; and
4. Recommendations for the most suitable courses of action, and a proposed timetable for their introduction.

Energy efficiency and conservation play an important role in promoting economic growth and helping Australia and New Zealand meet their energy challenges, such as enhanced security of supply and reduced greenhouse gas emissions from energy.

The following benefits arise from more energy efficient technology and practices:

- Enhanced economic growth through increased productivity;
- Improved energy security by reducing energy demand, including that for imported sources of energy;
- Reducing energy costs for consumers;
- Deferred need for more expensive energy supply by making better use of existing energy; and
- Reduced greenhouse gas emissions.

Data centres are high energy users with significant scope for improving the energy efficiency of their operation. In 2013 data centres consumed 7.3TWh (26.3 PJ) of electricity in Australia (3.9% of national consumption), and 0.9 TWh (3.24 PJ) in New Zealand (2.1% of national consumption). The trend is for increasing demand for the services provided by data centres (mainly data storage) due to growing use of information technology (IT).

Large new data centres use the latest energy efficient technology but older, smaller data centres generally do not. Energy efficiency would improve if smaller older data centres were retired. However, decision makers often lack the knowledge to choose an energy efficient data centre service, or they do not prioritise IT energy efficiency due to other pressures. There is a lack of knowledge available for improving current data centres and their operators often lack the time and budget to keep up with new technologies.

What is a data centre?

Data centres provide information technology (IT) services that underpin a vast range of activities in business, government, and society. These can range from streaming media and online shopping services for consumers through to the financial systems operated by banks and providing the management control for the supply of utilities across entire regions. Data centres have only been around for the past twenty years but can be considered as the factories behind the knowledge and information industry. Like many factories, they consume substantial amounts of energy in order to operate but, as is often the case with new and immature industries, they are undergoing rapid changes providing huge potential for energy efficiency improvements.

Definition: *A data centre is a structure, or group of structures, located on a single site dedicated to the centralised accommodation, interconnection, and operation of information technology and network telecommunications equipment that provides data storage, processing, and transport services. A data centre encompasses all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability.*

The data centre market

Unlike most of the other equipment covered by the E3 Program, data centres are not mass produced for a common market. Individual data centres are custom designed to meet specific geographical, business and client requirements. The major end users like the financial sector, telecommunications, and Government all have different needs of data centres in terms of IT services, reliability, and security.

In addition, the major parts that make up the complete data centre such the building itself, the carefully controlled air conditioning, IT equipment, software and applications may be managed by separate operation teams. This means that different business models and markets exist for all parts of the data centres' design and operations.

Two of the most common business models are colocation and IT service provision. With colocation, a client leases space within the building and the client installs and manages their IT equipment and software while the colocation provider manages the power and operating environment. With IT service provision, the IT equipment, software or applications are not owned by the client but are leased in some form depending on the clients' needs. Cloud computing is the best known way of providing IT services. It provides the services of a data centre through the internet without the client having any knowledge of, or direct relationship with, the data centre(s) from which their data services are being supplied. From an energy efficiency viewpoint, the large economies of scale means very high efficiencies tend to be achieved by data centres operating in the cloud computing market.

The size of data centres varies from a few kilowatts (kW) of power consumption to tens of thousands of kW. These, for reporting purposes, have been categorised as:

- Small data centres from 10 kW to 150 kW
- Medium data centres from 150 kW to 750 kW
- Enterprise data centres from 750 kW to 2 500 kW
- Mega data centres 2500 kW and larger

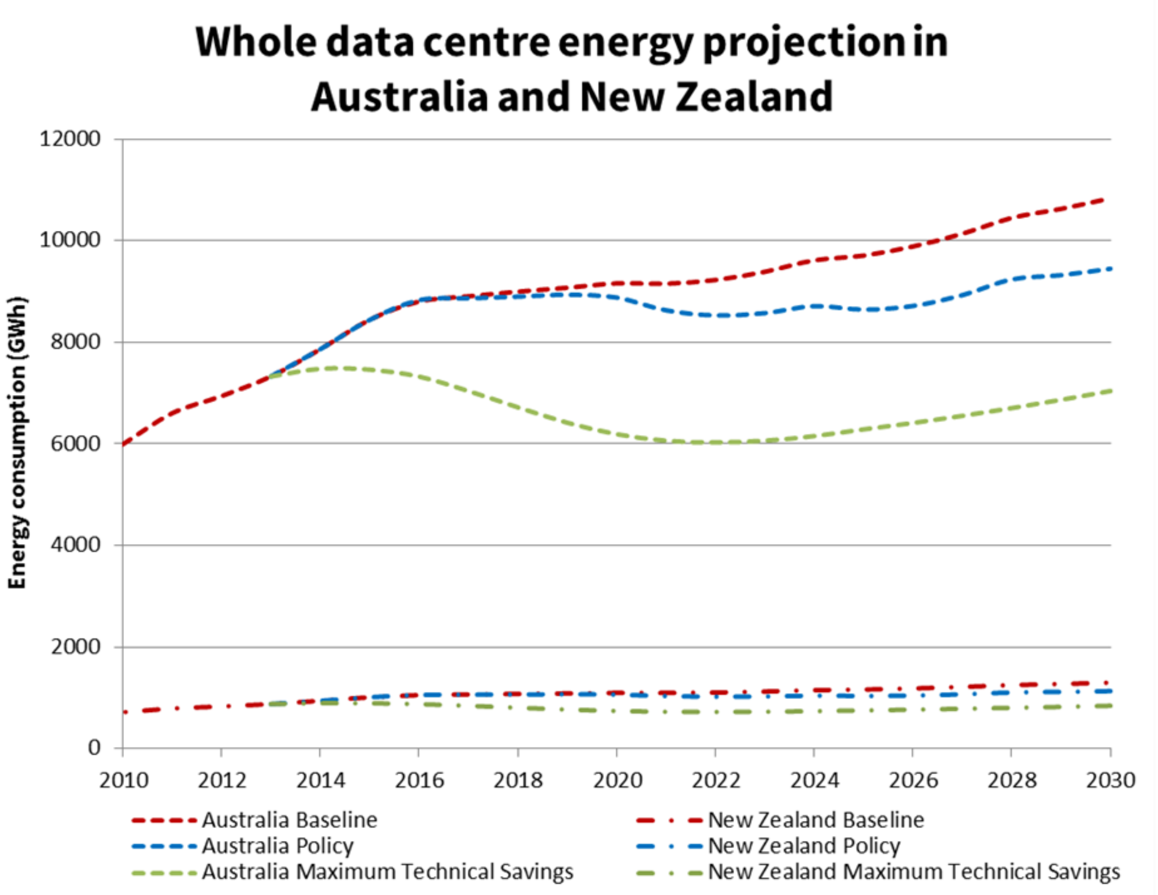
Data centre trends

There are estimated to be more than 40,000 data centres over 10 kW in Australia and New Zealand. Over 95% of these are small, between 10 and 150 kW, with enterprise and mega data centres over 750 kW accounting for just 0.4% of the total number of data centres. However, when calculated by total energy consumption, small data centres represent 39% of consumption in 2013, medium data centres 21%, enterprise data centres 32% and mega datacentres being the remaining 8%.

In general, data centre infrastructures built before 2009 were inefficiently designed and operated. In the enterprise and mega data centre market, these are being replaced by efficient designs using far less energy. However, the improvements available to small and medium data centre are more limited. The energy consumed by a large, new data centre infrastructure can be as little as 20% of a comparable collection of small, old and inefficient data centres. Since a data centre will typically operate for 10 years, the legacy of inefficient data centres means that the energy consumption is projected to continue to rise until 2016, before reducing slightly as the majority of older data centres will have been retired or refurbished.

By applying the best available technology and practices, the maximum technical (electricity) savings in 2025 are predicted at 3.8 TWh (13.7 PJ – the annual electricity consumption of 500,000 Australian homes), a reduction of 35%. Whilst this assumes that all individual data centres improve in efficiency, the majority of the savings arise from over 60% of small data centres being retired. They are replaced by cloud services housed in highly efficient enterprise and mega data centres that use just 20% of the energy. The savings from the policy lines being based on the policy recommendations and timeline proposed in this report. Implementing energy efficiency measures could reduce annual energy consumption by 11% in 2025 with cumulative energy savings of 10.8 TWh (38.9 PJ) in Australia and 1.3 TWh (4.7 PJ) in New Zealand by 2030.

Figure 1 Whole data centre energy projections in Australia and New Zealand



Policies and recommendations

The proposed policies are designed to address three key issues:

- Efficiency of IT equipment design;
- Data centre infrastructure efficiency in all sizes of data centres; and
- Encouraging and selecting data centres services delivered by more efficient enterprise and mega data centres rather than smaller data centres.

Policies for IT equipment

IT equipment technology and efficiency is improving rapidly, with new product generations released every year. Consequently, policies to support the uptake of the most efficient equipment need to be agile enough to keep pace with improvements. Adoption of High Efficiency Performances Standards (HEPS) such as ENERGY STAR can be implemented relatively quickly. Harmonisation with the US ENERGY STAR program means that there will be strong market coverage by equipment manufacturers supplying the small data centre sector.

However, it is possible to set more ambitious criteria than ENERGY STAR and this could be achieved using a mandatory comparative energy ratings label. New metrics for server and storage, SPEC SERT and SNIA Emerald, have recently been developed which means a label is now technically possible. New efficiency standards for servers are projected to be attained by 75% of the market in 2016. This is because the market is very competitive and to ensure the risk to sales is minimised, manufacturers will respond to achieve the highest rating for the most popular models. Based on an update every 4 years, the energy saving in IT equipment is estimated to be 1.7 TWh (6.1 PJ) for servers and 0.4 TWh (1.4 PJ) for storage between 2017 and 2030. Additional savings may also be achieved in the data centre infrastructure (primarily through a reduction in demand for cooling) as a result of the reduced IT equipment energy.

Policies for Data centre infrastructure

NABERS is a well-established policy that has successfully driven energy efficiency improvements in the commercial building sector in Australia. New Zealand has a similar policy called NABERSNZ which was established in 2013. NABERS is based on the actual energy consumption (also water, waste for some building types) and therefore addresses not just how well a building is designed but how well it is being operated. Operational inefficiency is an important consideration for data centres, and this is the most effective policy recommendation to improve it. NABERS ratings for data centres were launched in Australia in 2013 with three distinct parts: for the Infrastructure, the IT equipment and the Whole Data centre (a combination of both). The data centre infrastructure method is based on a well-established metric and therefore creating additional policies to further increase adoption of NABERS data centre infrastructure is recommended. New Zealand would benefit from adopting a suitable version of NABERS for data centres over the next few years.

Increasing adoption of NABERS data centre infrastructure rating to 75% of enterprise and mega data centres is estimated to save 3.5 TWh (12.6 PJ) or greater[1] by 2030. This is achieved through a recommended mandatory government procurement policy introduced in 2015, and mandatory disclosure of infrastructure efficiency for colocation businesses in 2019 which are based on NABERS data centre infrastructure ratings.

Small and medium data centre efficiency is less driven by market competition and therefore mandatory efficiency standards are needed. Building codes based on a NABERS target and its equivalent technical specifications are recommended. If this was introduced in 2020, it is estimated to cumulatively save 3.4 TWh (12.2 PJ) by 2030.

Policies for encouraging selection of efficient cloud and data centre services

Enterprise and mega data centres are much more energy efficient than small and medium data centres. This is a result of competition, resource and a skills gap between businesses whose primary operations require data centres and those who use data centres to support an unrelated business activity. Increasing awareness of the energy efficiency advantages of the larger data centres and enabling users to make direct comparison between services and service providers should result in the workload of these efficient centres increasing with a commensurate impact on the smaller less efficient data centres.

It is recommended that data centre service metrics are developed and a voluntary data centre services rating scheme is introduced by 2018. It is projected this will save 2.9 TWh (10.4 PJ) by 2030.

The provision of this information then enables the development of procurement guidelines. These would benefit the operations of Government Agencies as well as being a beneficial influence on other businesses. Government could produce or encourage the provision of other guidance too, such as

- Guidance for existing financial mechanisms and loans to establish methodologies to calculate savings and financial returns from investing in different types of energy efficiency improvements including virtualisation and migrating services to more efficient data centres.
- Guidance on selecting and using advanced metering of energy and IT utilisation to improve internal efficiency metrics.

Other policies and considerations

A number of additional policies and activities were also considered but the small impact or likelihood of influencing policy means they are not strongly recommended.

Minimum efficiency performance standard for uninterruptible power supplies (UPS)

The UPS is a small part of the data centre infrastructure and therefore is already covered by Buildings Codes and NABERS. A high efficiency performance standard could also be introduced before the MEPS and create additional savings. The total savings are estimated to be 0.26 TWh (0.9 PJ).

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[1] Savings estimates based on Government procurement targets minimum standard of 3 star 2015, 4 star 2020.

Minimum efficiency performance standard for IT equipment power supply units (PSU)

The PSU for the majority of servers already achieves a high efficiency. Introducing a MEPS in 2016 could potentially increase the efficiency by approximately 3% for 30% of the whole IT equipment market. This is estimated to save 0.17 TWh (0.6 PJ).

Training and certification of IT professionals

Operational efficiency of the data centre (as opposed to design efficiency) is not well covered by the policies recommended and can be a significant factor in the overall efficiency. Training, certification of IT professionals and auditing by energy efficiency experts could play a key long term role in improving energy efficiency. However, more research is required to understand what is needed and if there is a policy role.

Research

The importance of research in this field has lately been recognised for the energy saving potential but also the economic potential from market opportunities that are arise from creating and developing skills and knowledge. A number of relatively large international research projects are underway to understand key areas of the data centre. This includes the benefits of training, renewables, and software efficiency.

In Australia, the National Cloud Computing Strategy has made similar statements and could present an opportunity for collaboration.

Renewables

Compared to efficiency improvements, renewables as a part of data centre buildings are not cost effective. A single large data centre will consume the same amount of energy as a large commercial renewable project can provide. This means that the capital and investment commitment is very high. Making such investments is subject to highly regulated electricity markets.

Cogeneration efficiency is achieved by the ability to use waste heat, cooling and electricity capacity within the local site or community. This is determined by local planning regulations and the ability of the local community to make best use of the spare capacity. As they are beyond the scope of the project, renewable and cogeneration policies have not been recommended in this report.

International harmonisation of policies and metrics

A number of policies might also benefit from harmonisation with international efforts, although in general most international efforts are too small and immature to recommend harmonisation at this time. The best candidates for harmonisation are in the development of metrics, ENERGY STAR and SPEC SERT for servers, Open Data Center Alliance (ODCA) for data centre service metrics and an ISO standards for data centre infrastructure energy efficiency (power usage effectiveness - PUE) measurement. Best Practice guidance from the EU Code of Conduct for data centres also could be used for training and providing improvement advice for data centres.

Summary of policy recommendations

Table 1 Timeline and prioritisation for policy implementation

Timeline	Higher priority	Lower priority
2015	NABERSNZ to adopt data centres metric Government data centres procurement set at NABERS data centre infrastructure two tier 3 star minimum/4 star recommended	-
2016	IT servers HEPS/rating label, Introduction of a metric for data centre services	ENERGY STAR UPS, Cloud energy awareness raising

Timeline	**Higher priority**	**Lower priority**
2017	Data centre energy efficiency website portal, Finance guidance, Data Centre Information Management guidance	IT storage HEPS/rating label, UPS MEPS, Research training opportunities
2018	Data centre services rating	Research strategy
2019	Mandatory disclosure of NABERS DC rating for colocation facilities	-
2020	Building Codes introduce energy metering and energy efficiency requirements for new and refurbished data centres. Government data centres procurement rises to NABERS data centre infrastructure 4 star minimum/5 star recommended IT Server HEP/rating label updated	-
2021	-	IT storage HEPS/rating label updated
2022/2023	-	-
2024	IT Server HEP/rating label updated	-
2025	-	IT storage HEPS/rating label updated

Further consultation would need to take place before any policies are implemented, and some policies are for the consideration of government departments outside of the E3 Program.

This report is a discussion document and seeks comments on the proposed policies, any new and relevant information on data centre IT would be welcome.

Glossary and abbreviations

Term	Description
ACS	Australian Computer Society
ARM	A semiconductor design computer and a CPU architecture
ASHRAE	ASHRAE is a building technology society that focuses on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry.
Blue Angel	A German certification for products and services that have environmentally friendly aspects
BREEAM	BRE Environmental Assessment Method is a method of assessing, rating and certifying the sustainability of buildings (BRE was the UK's Building Research Establishment)
CEEDA	Certified Energy Efficiency Data Centre Award is a data centre certification scheme
CEFC	Clean Energy Finance Corporation
Cloud Computing	Internet and network-based services, which appear to be provided by real server hardware, and are in fact served up by virtual hardware, simulated by software running on one or more real machines
cogeneration	the simultaneous generation of useful heat and electricity to increase efficiency
colocation	A type of data centre where equipment, space, and bandwidth are available for rental to retail customers
DC	Data centre
DC infrastructure	The power, cooling and other systems in a data centre to support the IT equipment
DCIM	Data Centre Information Management
DCMM	Data Centre Maturity Model
EE	Energy Efficiency
EECA	Energy Efficiency and Conservation Authority
EEO	Energy Efficiency Opportunities Programme
ENERGY STAR	An international energy efficiency product certification scheme
ETSI	European Telecommunications Standards Institute
EU Code of Conduct	EU Code of Conduct for Data Centres is an energy efficiency program focussed on data centres
EU ErP	EU Energy related Products Directive
FVER	Fixed to Variable Energy Ratio
GHG	Greenhouse Gases

Term	**Description**
GWh	Giga Watt hours, one million kWh
HEPS	High energy performance standards
HVAC	Heating ventilation and air conditioning
ISO	International standards Organisation
ICT	Information Communications Technology (same as IT below)
IT	Information Technology
IT equipment	IT equipment is the servers, storage and networking equipment housed in a data centre
IT load	The power demand placed on the data centre by the IT equipment
ITU	International Telecommunication Union
kW	kiloWatt, a measure of power
kWh	kiloWatt hours, a measure of energy
LEED	Leadership in Energy and Environmental Design, a standard for green building design
microserver	A microserver uses many small independent nodes, around 50, consisting of a CPU and RAM into a server which normally houses 2 to 4 CPUs. While each node's processing capability is more limited it is designed to perform this limited processing more energy efficiently and across many nodes
MtCO2e	Mega tonnes of carbon dioxide equivalents
NABERS	National Australian Built Environment Rating System
NCCS	National Cloud Computing Strategy
OCP	Open Compute Project
ODCA	Open Data Center Alliance
PJ	Peta Joule, equivalent to 0.28 TWh
PSU	Power supply unit
PUE	Power Usage effectiveness a measure of data centre efficiency
SERT	Server Efficiency Rating Tool
Server	A specialised type of computer generally accessed over a network by client devices.
SME	Small and Medium Enterprises
SPEC	Standard Performance Evaluation Corporation
SPECpower	A metric to measure server power and performance
The Green Grid	a non-profit, industry consortium of end-users, policy-makers, technology providers, facility architects, and utility companies collaborating to improve the resource efficiency of data centres
TIA	Telecommunications Industry Association
TWh	Tera Watt Hours, one billion kWh

Term	**Description**
Trigeneration	the simultaneous generation of useful heating, cooling and electricity
UPS	Uninterruptible Power Supply
Virtualisation	Refers to the creation of a virtual machine that acts like a real computer with an operating system. Software executed on these virtual machines is separated from the underlying hardware resources
White space	Refers to the usable floor area for IT equipment.
WRI GHG Protocol	World Resource Institute GHG Protocol is a series of reporting guidelines for businesses to report GHG emissions

1. Introduction

This Report was commissioned by the Equipment Energy Efficiency (E3) Program to investigate suitable policy options to improve energy efficiency in Australian and New Zealand data centres. In particular, the report includes:

1. Trends in data centre numbers, energy consumption and growth;
2. Energy efficiency policies for data centres and barriers to such energy efficiency improvement;
3. Recommendations for the most suitable course of action, and a timetable for introduction.

The E3 Program is a joint initiative of the Australian, State and Territory governments and the New Zealand Government. Improving the energy efficiency of appliances and products has significant economic and environmental benefits for Australia and New Zealand. It reduces greenhouse gas emissions and energy demand in both countries. It also reduces the running costs of appliances and products for households and businesses.

The broad policy mandate of E3 has been regularly reviewed over the last decade and was most recently modified in 2004. Any equipment that uses energy could be regulated provided such intervention can be justified after study and finalisation of a further Regulatory Impact Statement that demonstrates cost-effectiveness.

To be included in the program, appliances and equipment must satisfy certain criteria relating to the feasibility and cost-effectiveness of intervention. These include potential for energy and greenhouse gas emissions savings, environmental impact of the fuel type, opportunity to influence purchase, existence of market barriers, access to testing facilities, and considerations of administrative complexity. Policy measures are subject to a cost-benefit analysis and consideration of whether the measures are generally acceptable to the community. E3 processes provide stakeholders with opportunities to comment on specific measures as they are developed.

1.1 Background to data centres and IT

Information Technology (IT), the application of computers and telecommunication equipment to process, store, receive and transmit data, is being applied to an ever growing range of services. The data centre not only stores the IT equipment to provide IT services but protects it against disruption and ensuring it can operate reliably and securely. The reliability of the data centre is an important factor in the growth of IT and has enabled society's complete reliance on IT to manage everyday tasks as well as critical infrastructure. This industry is relatively new and the modern data centre as described above only appeared around 1990 in the USA alongside the rise of the internet. As a result, there have been many changes as they have evolved and matured - both in terms of technology within the data centre as well as the businesses and structure of the market. To provide a clear understanding of what is and is not a data centre, **Section 2 Data centre definition** of this report describes the component parts of the data centre and provides a definition on which the content of this research report is based.

The structure of the data centre market, in terms of the types of services provided to – and by - data centres, completes the overall picture of data centres in Australia and New Zealand. Knowing who are the largest data centre operators and what the data centres are used for provides important insights into the policies which can be applied, and where the focus of such policies should lie. This is covered in **Section 3 Data centre types** of this report.

The growth of the data centre market and its related energy consumption and environmental impacts only rose to attention in 2008, with the US EPA report to Congress showing rapidly rising energy consumption for data centres in the USA - but also potentially high savings. It is logical that attention was first paid in the USA since it historically and currently has the biggest influence on the market, in terms of equipment design and manufacture as well being the home to many of the largest internet companies. However, compared to other types of office and household equipment covered by programs such as E3, international research to understand the trends in data centre energy consumption has been relatively limited. Therefore, the first essential step is to project the energy consumption which can then guide subsequent policy analyses and recommendations. **Section 4 Energy modelling and projection** of this report describes the modelling approach and the energy trends it has projected.

Despite information on trends being somewhat limited, from a technology perspective there have been many improvements to data centre efficiency in the past five years. These have been practically demonstrated in a number of high profile examples of extremely high efficiency data centres constructed around the world. For a given User IT service, it is entirely possible that over 90% energy savings can be realised compared to an older, inefficient, data centre. However, to achieve such savings is not within the remit of a single technical discipline. Within the data centre there is a broad range of equipment and technologies, such as the software, IT equipment, the environmental control equipment and power equipment. This cuts across a range of different technical and engineering disciplines such as building engineers, electrical engineers, and IT hardware and software engineers. Achieving maximum savings therefore requires deep understanding of all these individual areas and their interactions, while ensuring the core function of resilience and reliability is not undermined.

The wide range of technical disciplines impacting on data centres also cuts across a number of generally discrete environmental and energy efficiency policy areas. These include building and planning codes, equipment efficiency (in design), environmental management and operational best practices. The policy analysis in this report attempts to cover all areas of policy to try to establish the most suitable approach. This necessarily goes beyond the policy scope of the E3 Program. The policy timing must also be considered as the area is still developing and the market may not be mature enough or suitable to apply policies without further changes and developments. The policy analysis is found in **Section 5 Opportunities to improve efficiency**.

There are a number of international policies in effect covering different aspects of the data centre efficiency. Policy harmonisation makes development and market coverage more effective as well as reducing the burden for the industry. This is discussed in **Section 6 international programs**.

Based on the research, a final recommendation and timeline is developed taking into account the savings, and policy development process. This is presented in **Section 7 A recommended course of action…**

2. Data centre definition

2.1 Introduction

This Section sets forth the requirements for defining a data centre and analyses the current existing definitions for data centres. From these, a definition is developed for this report and for future policy applications.

2.2 Basic description of the data centre stack

This section introduces some basic concepts and simple definitions which are required to understand the discussion in this report.

The data centre stack (Figure 1) describes the different layers within the data centre from the physical structure to the final useful IT service being provided. Within each layer are also distinct domains of operation. This gives an overview and understanding of the technical elements and dependencies which make up the data centre and influence the overall energy efficiency.

Figure 1 Basic data centre stack

	User IT Service/business process		
	Applications		
System software	Operating System, Virtualisation		
IT Equipment	Server	Storage	Networking
Infrastructure	White space	Power	Cooling
	Data Centre		

A **data centre** is used to house IT equipment which is providing some sort of User IT service to users connected remotely via a network. The basic physical description starts with the **white space**, a physical space which is used to house the IT equipment. This can be a room within in a larger mixed-use building, most commonly an office block, or within a dedicated building.

The **data centre infrastructure** ensures the IT equipment works reliably and generally includes cooling equipment and power equipment. The **cooling equipment** encompasses a range of environmental control equipment to manage temperature, humidity and particulates - all of which might affect the IT equipment reliability. However, from an energy consumption and cost perspective, it tends to be dominated by the cooling equipment, including mechanical chillers and compressors (air conditioners), fans, as well as newer 'economiser' cooling which uses the lower temperature of outside air or water to provide cooling. The **power equipment** distributes the electricity to the IT equipment and ensures it is clean and free from fluctuations or instability. This includes providing alternative power supplies, generally through uninterruptible power supplies (UPS) which almost always contain batteries for short term power loss and generators for longer term power loss in the event of total electricity grid power loss. To ensure the power and cooling equipment does not fail, it is common to have a number of additional backup units or to run equipment in parallel. Such additional equipment often runs below maximum capacity.

The **IT equipment** provides the IT services, which can be separated into networking, storage, and data processing functions. While dedicated IT storage, IT networking, and IT processing equipment is now used in larger data centres, the main piece of IT equipment is the **IT server**. This, at a minimum, provides the processing capabilities but almost always also includes some storage and networking functions within its physical housing. Redundant power supply units (PSUs) within the IT equipment are often installed. In some cases, the IT equipment may be duplicated and all data processing and storage duplicated too, to reduce the risk of failure or error.

The IT equipment will run **system software** such as management, virtualisation and the operating system. Running on top of the system software are the **applications** which provide the useful User IT services and business processes.

2.3 Existing definitions

A number of definitions already exist within technical documentation such as TIA 942[2] and policy documents such as the EU Code of Conduct and NABERS. A commentary on the content of these, and some data centre definitions published by other bodies, is given in Appendix A.

Some explanations of the key features of a data centre that can be described in existing definitions are described in Table 1.

Table 1 Key features of a data centre

Data centre feature	**Description**
Physical space	This covers the area in which IT equipment is housed, or in which data processing occurs. Most definitions are clear that it can be an entire building or a room within a building providing multiple uses. Some definitions explicitly distinguish between the datahall (housing the IT equipment) and the data centre (the larger building structure including datahall support infrastructure). There is generally no maximum size, but a minimum size is sometimes defined, or is set as a proportion of the overall building size. The definitions vary in the inclusion of the auxiliary spaces that provide services to the data centre, though they are generally included. Some definitions such as BREEAM include ancillary spaces for personnel running the data centre such as gyms and meeting spaces while others exclude it, such as the Australian draft report definition. Including the spaces may make it easier for reporting and monitoring where not every space is separately metered, but would give a less accurate PUE. The Green Grid definition contains reference to multiple possible structures, rather than a single building or room.
Power consumption	ASHRAE and ENERGY STAR mention high power consumption or high power density
Function	There are various definitions referring to the housing of various types of IT equipment, and the provision of data and IT services. ENERGY STAR explicitly mentions and excludes Computer labs.
Environmental control	Definitions generally refer to the cooling equipment but generally do not identify its purpose, i.e. environmental control.
Security	Only mentioned by The Green Grid (and possibly Blue Angel). This is a key feature of many Data Centres but may be unnecessary for a definition.

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[2] TIA (Telecommunications Industry Association) 942 is a telecommunications Infrastructure Standard for Data Centres and is an American National Standard that specifies the minimum requirements for telecommunications infrastructure of data centres and computer rooms including single tenant enterprise data centres and multi-tenant Internet hosting data centres

Data centre feature	Description
Resilience	Resilience refers to the data centres' ability to recover from disruption such as power failure or hardware failure. This is generally, but not necessarily, provided by installing redundant and backup equipment. This concept is only mentioned by The Green Grid but is another key feature of a data centre. Redundancy in the power and cooling supply is mentioned in other definitions.
Dependency on other definitions	Many refer to particular types of equipment such as servers, UPS, switch rooms generally as examples but sometimes as requirements.

2.4 Discussion of definition

Ideally the definition should capture all facilities which exhibit the same energy consumption efficiency improvement potential and limits. It should not include any other types of building or facilities for which the policy or technical discussion is not relevant. For mandatory policies in particular, it is very important that the definition is not too broad, since this would set legal requirements which may be impossible to meet and may create negative economic impacts. In addition, the definition should be stable for any data centre to ensure it is clear whether it is in or out of scope.

Definitions tend to be either functional or technical. A functional definition is based on the services provided by a product or building. This has the benefit of being more adaptable to technical changes but cannot be so precisely defined. A technical definition is based on specific technologies which can uniquely identify the product. This is often preferred in regulations since it is easier for manufacturers and compliance groups to determine if a product falls under a definition.

Since policies may be applicable to only a subset of data centres, such as carbon trading for large data centres, the data centre **definition** should also provide a way to clearly define or limit the **scope** of these policies in a consistent manner.

It is also important to consider future technology changes which may influence the approach taken by current data centre designs. This could result in a confusing and inconsistent market, especially for clients trying to compare data centres.

Physical space – The definition should allow the facility to range both in size and in the number of structures in order to capture all the various designs. In particular, to ensure new modular and containerised designs are covered whose limited size could otherwise result in exemption from policies, even though they are operating as a single larger data centre. The data centre definition should be limited to a single location to ensure that remote data centres are not included even if they are operated together. This is because there may be other reasons for choosing to site the data centre in multiple locations such as security and proximity to customers. This also sets a clear boundary between the Wide Area Network of the internet and the data centre networking equipment.

Note that the energy consumption of the national telecommunication network equipment needed for long distance data connectivity is outside the scope of this report.

IT equipment – It is preferable not to explicitly mention types of equipment such as networking, storage, or servers. This is because future technologies are likely to change how the equipment is designed and connected.

Dedicated to/primarily/exclusively for – the definition needs to be clear that a facility that is also designed for continuous human occupation and comfort, such as a computer lab, is not included.

Resilience and service availability - while other definitions directly reference mechanical cooling and power, the primary purpose is to ensure the IT service, not the equipment, is reliable. Techniques and technologies are being developed to enable resilience, in particular through software, which may result in the definition becoming obsolete. However it is very likely that resilience will continue to be a primary function of a data centre as it ensures security of data in a changing environment.

Data centre size - data centres can be sized in a number of ways such as the floor area, total power consumption and the IT Load. Since the IT Load most closely represents the useful work done, this is preferred over the total data centre consumption. Floor area is not used because the energy density i.e. power per square metre has tended to increase over time resulting in smaller data centres for a given power consumption. Since these policies are directly related to energy efficiency, the power consumption of the IT equipment is the primary concern. In addition, by using the maximum load, it is less likely that the data centre size will change or fluctuate over the short term. This is important from a policy perspective when mandatory regulations may apply.

2.5 Recommended definition

Based on these features the Green Grid definition is the most suitable, and could be adopted with slight modification:

A data centre is a structure, or group of structures, located on a single site dedicated to the centralized accommodation, interconnection, and operation of information technology and network telecommunications equipment that provides data storage, processing, and transport services. A data centre encompasses all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability.

In addition a definition of data centre size is proposed to set the scope:

Data centre size –the data centre size is defined by the maximum power load, measured in kW which the data centre can supply to the IT and telecommunication equipment while still providing the intended level of resilience and service availability.

This differs from NABERS which defines the scope based on the operational IT load rather than the designed load. The design load is preferred because it will remain relatively stable over the life of the data centre, with expansion being a planned and infrequent event. The operational IT load however can vary on a daily or hourly basis, which can make it difficult to determine whether or not a data centre is within scope.

The proposed scope of this project is to cover the data centres with a size greater than 10 kW IT load.

2.5.1 Additional definitions

A number of additional definitions are considered useful to describe the data centre:

- IT load – the IT load is the energy consumption of the IT equipment in the data centre. A precise definition is needed to measure the PUE. Since the NABERS measurement already provides a rigorous way to determine the PUE. This definition should be used to define IT load and ensure consistent national policies.
- Servers, storage and networking equipment – the ENERGY STAR definition should be used since this has been developed with strong stakeholder and industry input.

3. Data Centre Types

3.1 Introduction

Data centres and data centre services are used by almost every industry. For most industries, these services are simply ancillary to the main business such as email, file-sharing and web hosting. A few industries require data centres to undertake their core business operation such as the financial sector. Finally, for the dedicated data centre providers, such as colocation and cloud, the data centre forms their core business. This Section describes the data centre market within Australia and New Zealand and the market and capabilities from each sector.

3.2 Description of the data centre market

The data centre market is not homogeneous and there are many different niches within the industry. The first distinction to be made is the two types of data centre services:

1. Services supplied to the data centre industry such as design, operation, supplying new equipment.
2. Services provided by the data centre such as cloud services, web hosting.

Returning to the data centre stack, in Figure 1, these services provide one or more of the domains identified. Services provided to the data centre may be outsourced or managed in house. They are an important element to understand since they can impact how policies might apply to the data centre. For example, product labels would primarily affect the manufacturers of the equipment deployed within the data centre, but could also influence the purchasing decisions being made by the data centre's operator.

Services provided by the data centre tend to start from the system software and the layers above. By removing the complexity of operating and maintaining the equipment itself, the business is able to focus on the services it provides.

In theory, the more domains within the data centre that come under one control enables greater optimisation of the whole data centre. Conversely, shifting control of individual domains to specialists with expert knowledge means that domain subsets can be fully optimised using the best technology and operating techniques.

3.3 Common business models

Some of the more common business models within the data centre industry are:

- Data centre/real estate management generally own (or lease) the building and land. They may also install the DC infrastructure but often will not operate or manage it and therefore have limited control of the efficiency.
- DC infrastructure management – similar to other building management contracts they will manage the infrastructure to meet client requirements. Energy Service Companies (ESCo) business models are becoming more common within this sector whereby the client and the contractor profit share in any efficiency improvements and investments made.
- IT services in this instance refers not just to the User IT service/business process, but can also include management of the IT equipment, the system software and applications.
- Colocations will operate and manage the data centre infrastructure, and lease the managed space and electricity to clients to run their own IT equipment. They may also provide networking connecting the data centre to the internet. Colocation providers have control of the power and cooling efficiency but must also meet client environmental demands.
- Cloud computing converts the physical IT equipment into a large pool of data processing, storage and networking resource which can be broken up into smaller virtual units, and which can be sold and accessed on demand by the user. By using scales of economy, the IT services are essentially commoditised and it is possible for the operator to maximise the use of the data centre and IT equipment across many users as well as being able to scale up and down with user demands. Cloud computing is currently described at a number of levels:

- Infrastructure as a Service – provides virtual servers
- Platform as a Service – provides virtual applications
- Software as a Service – provides business process/User IT services.

3.4 Data centre sizes

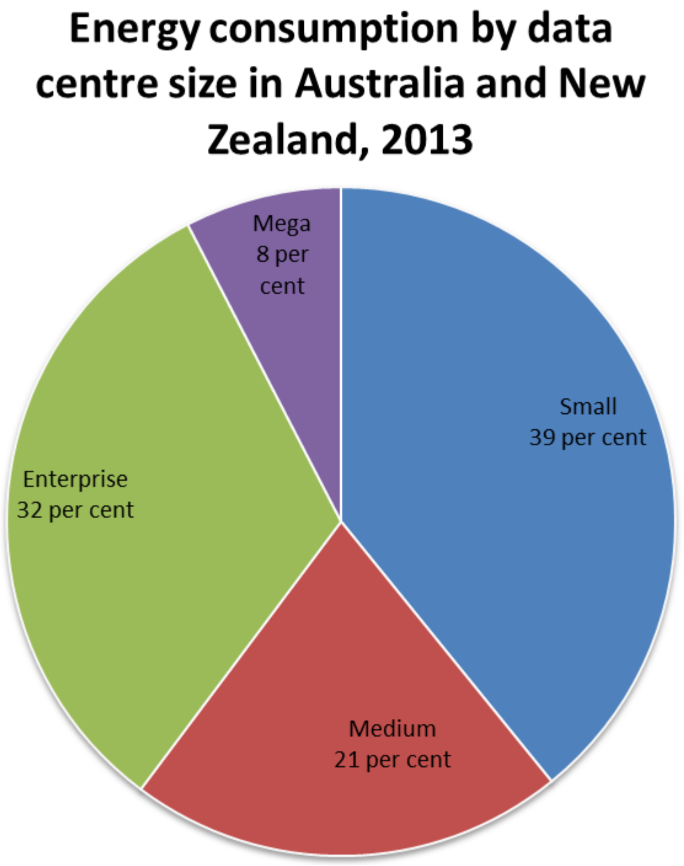
The recommendation in Section 2 is that the data centre size is defined by the IT electricity load it can provide, with a lower limit set to 10 kW. Based on this, data centres currently vary in size by three orders of magnitude, from 10 kW to over 10 MW (10 000 kW). This large variation reflects the different sizes of the business operating data centres as well as the User IT services being provided. When considering the data centre services and the business models, it is clear that they are not the same and consequently individual policies are unlikely to be applicable across the entire size range.

For this research, the data centres were split into four distinct sizes based on available market research data from Datacentre Dynamics Intelligence, but also reflective of the policies and business models. The four sizes are:

1. Small data centres from 10 kW to 150 kW
2. Medium data centres from 150 kW to 750 kW
3. Enterprise data centres from 750 kW to 2 500 kW
4. Mega data centres 2 500 kW and larger

The results of the modelling described in Section **Error! Reference source not found.**, show the projected nergy consumptions of the different sized data centres. These show that the small data centres consume 39% of the total energy despite consuming the smallest amount individually.

Figure 2 Energy consumption by data centre size in Australia and New Zealand, 2013

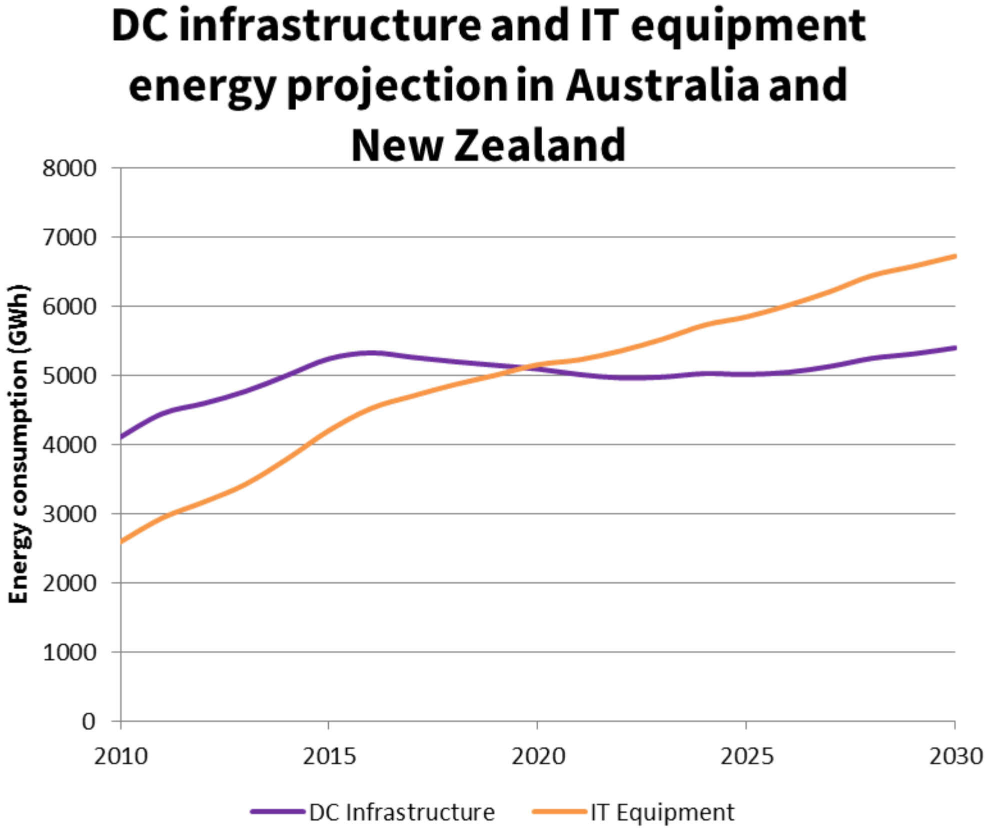


3.5 Data centre infrastructure vs IT equipment

It is common to divide the data centre into two parts; the IT equipment and the layers above, and the data centre infrastructure and below. This is because the IT equipment is understood to be carrying out the useful work, while the infrastructure, though essential, is a source of inefficiency. It also separates the two major technical areas between the mechanical and electrical engineering from the electronic and IT engineering.

Based on the modelling, the energy consumption for the data centre infrastructure in 2013 is 4.8 TWh (17.3 PJ). This is larger than the IT equipment which is estimated to consume 3.4 TWh (12.2 PJ). The IT equipment energy consumption is projected to rise steadily until 2030 to a maximum of 6.7 TWh (24.1 PJ), although at a slightly slower pace from 2016. However, the data centre infrastructure energy consumption actually falls very slightly from 2016 but overall remains relatively flat. This means the efficiency improvements in the data centre infrastructure under the baseline scenario are offsetting the increasing IT equipment load.

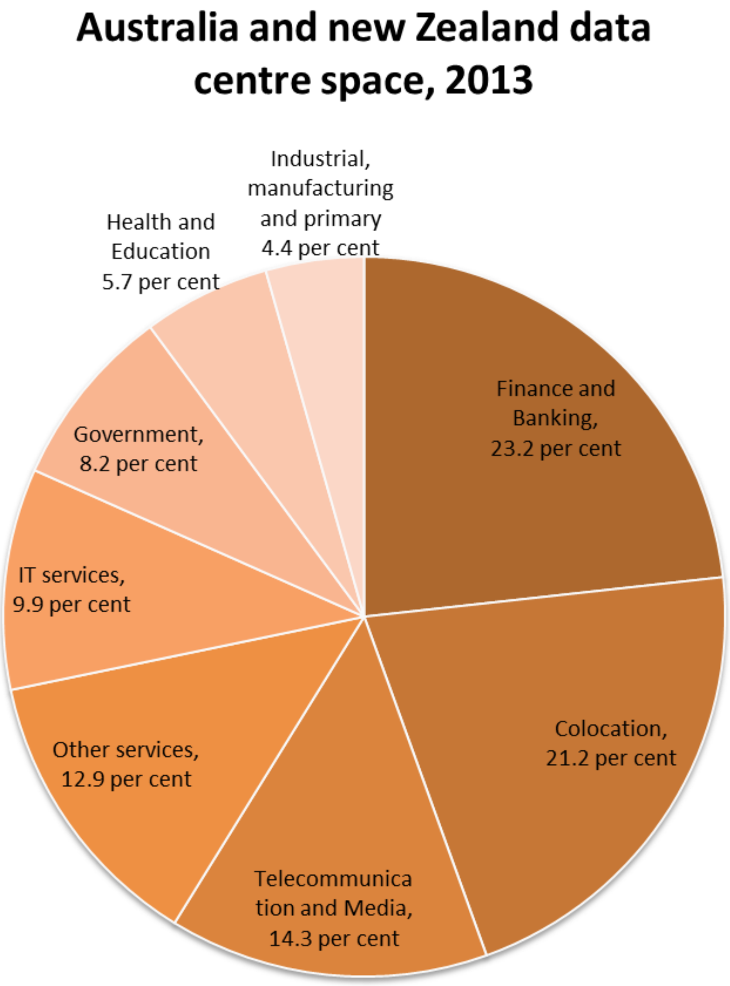
Figure 3 Data centre infrastructure and IT equipment energy consumption projections in Australia and New Zealand



3.6 Data centres by sector

DatacenterDynamics Intelligence (Parfitt, 2013) market research shows the current size of each data centre sector in Australia and in New Zealand (Figure 4). This is based on data centre space. Assuming this can be used as a proxy for data centre power, including IT and infrastructure, applying this to the energy modelling in Section **Error! Reference source not found.**, the estimated energy consumed by sector for Australia and ew Zealand are shown in Figures 5 and 6.

Figure 4 Australia and New Zealand data centre space (Parfitt, 2013)



These figures show that finance and telecoms are the largest single end user sectors. The private business sector is also large but this is comprised of a diverse group of different users. The Government sector at 8.2% is also a significant consumer. Colocation services, which host IT equipment for customers, are approximately half the size of IT services provided by data centres. While the currently available information mixes together data centre types and end user centres, there is also significant overlap between them as end users also use colocation and IT services. This means the end user sectors may be larger than represented.

Figure 5 Australia data centre energy consumption by sector in 2013

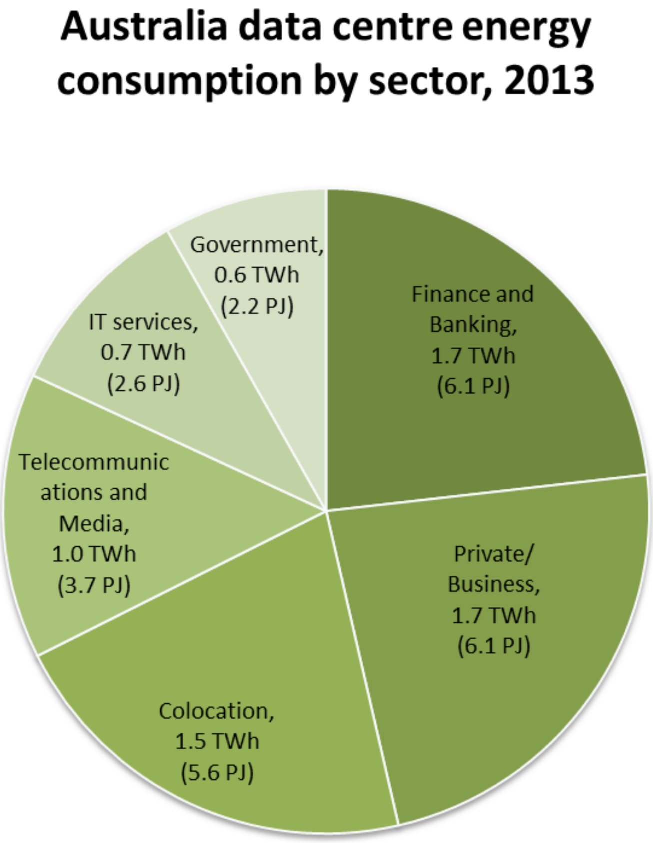
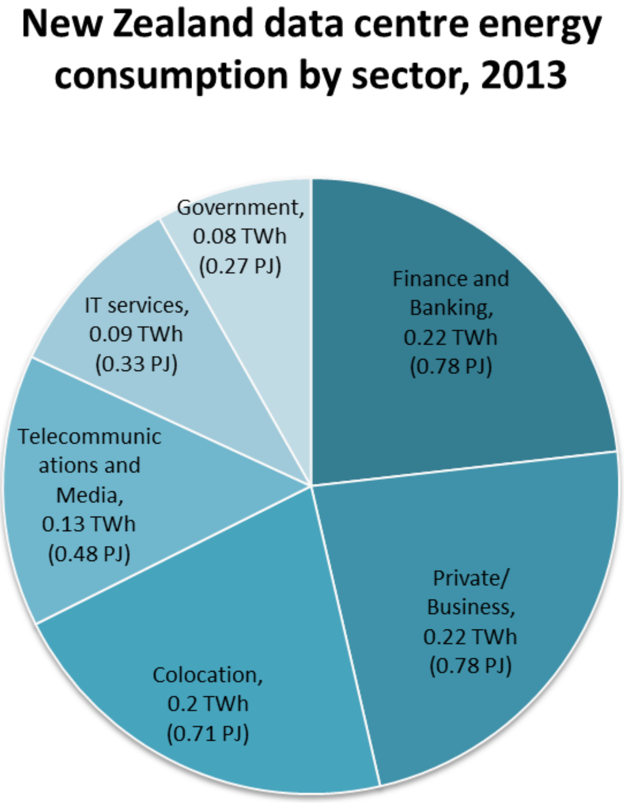


Figure 6 New Zealand data centre energy consumption by sector in 2013



3.6.1 Government sector

This sector includes the Australian Federal Government, or the New Zealand Government, as well as the State and local government agencies but not major public sectors such as health and education. The Australian Government sector has a clear strategy for improving efficiency. It has also adopted a “cloud first” strategy to make best use of the agility and low cost of these services. Government data centres often have very high data security and resiliency requirements for department IT services such as the Treasury. The Government sector often makes use of colocation and IT service suppliers with direct control only of the business process, though smaller departments have less sophisticated IT requirements. The New Zealand Government was also rated as world leaders for their Green IT procurement policies by Fujitsu[3] (2012).

3.6.2 Finance and banking sector

Finance and banking has very large IT requirements. It needs high resiliency and very fast response times. It has requirements for processing transactions where millions of dollars of transaction occur every second. In addition, they also have high computing requirements to perform complex statistical modelling for financial risk simulations that do not have lower time and resiliency requirements. Finally, the finance sector has very high data security requirements and needs to comply with regulations that require storage of transactional data. Because of the security risks, the finance sector has in the past had full control of the data centre and has been very conservative about making changes. More recently, they have been adopting outsourced services for lower risk activities.

3.6.3 Telecommunications and media sector

Telecommunications are unique because the data centres often need to be more geographically diverse to manage the distribution of data across the internet. Because they form the backbone of the internet, the data centres are highly resilient and in the past have used specialised hardware capable of operating across a wide environmental range. The media sector is also growing as more forms of entertainment are provided over the internet. Streaming and downloading require a large amount of bandwidth and storage. In addition, to ensure that all users can access the media quickly, the data centres and data tend to be duplicated and distributed in order to match population centres.

3.6.4 Private/business sector

This is a mixture of different and diverse sectors that can be seen in Figure 4 and this also includes some public sector services including healthcare. The diversity in sectors and business sizes also means that a wide range of data centres services are provided and there is a range of skills and capabilities. Most of the small and medium data centres are likely to found in this sector.

3.6.5 IT Services data centres

As discussed previously, these provide clients with support and operation of IT and software, including cloud services. Such providers do not necessarily have direct control of either the DC infrastructure or the IT equipment and may prefer to outsource this to colocation and other IT services providers.

3.6.6 Colocation data centres

Colocation data centres provide the data centre and operation and management of the infrastructure in order to host the IT equipment of the client. As a result, they have control over the power and cooling infrastructure only and provide the operating environment demanded by the client. Colocations therefore have a strong business incentive to improve the infrastructure efficiency as this minimises their operating costs and maximises profit.

However, there are three main reasons why the benefits of colocation can be difficult to realise:

1. Client contracts for hosting their IT equipment may include terms and conditions such as very low operating temperatures which prevent the data centre from operating optimally.
2. Demand outstrips supply meaning that clients have no choice but to host in less efficient data centres environments.
3. Migrating equipment to a more efficient data centre is a costly and risky process, and the client may be committed into a long contract.

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[3] http://www.fujitsu.com/downloads/AU/Fujitsu-Sustainability-The-Global-Benchmark-Report-2012.pdf

4. Energy modelling and projection

4.1 Introduction

The purpose of the model is to provide a first order estimate of current energy consumption by data centres in Australia and New Zealand, and forecast the energy consumption under different policy scenarios. Although the model is generally limited by the quality of publicly available data, it nevertheless provides useful guidance and indicative estimates of savings that can be made through various policy and technical solutions.

4.2 Model Structure

The model itself is adapted from the modelling approach used in the *Report to Congress on Server and Data Centre Energy Efficiency Opportunities* (US EPA, 2007). It is based on a number of variables which describe quantitative, technical attributes of the data centre:

- Number of servers. The server is the basic unit of computing in this model.
- IT equipment power consumption
- IT equipment utilisation e.g. CPU load
- Virtualisation rates
- IT storage and networking power consumption
- Data centre PUE[4]
- Number of data centres and data centre size

Therefore the energy consumption calculations for any given year are:

- IT server energy consumption = IT server power consumption (adjusted for its average utilisation level) x time used
- Total IT server energy consumption = IT server energy x total number of servers
- Total IT equipment energy = total IT server energy x IT Factor proportion of storage and networking
- Total data centre energy consumption = Total IT equipment energy consumption x PUE

There are a number of server sub categories and data centre sub categories which allows more granular modelling of data centre and server characteristics.

Since all these factors change over time due to the introduction of new technology and other market forces, time series must be built up for each of these variables and forecast into the future. These time series are developed by collating the various data sources and information available, as well as using our best judgement and assumptions.

4.3 Key trends and assumptions in baseline projection

This section describes how the baseline projection is developed from the available research and other data, combined with assumptions where data is unavailable. This starts with the current (2012/13) and historical data then a qualitative description of future trends. The Tables provided later in this section go on to show how the information has been converted to quantitative data for key points and assumptions in time. The full set of inputs and tables can be found in **Error! Reference source not found.** – Data for Modelling.

The baseline projection provides the business as usual trends against which different policies and energy saving options are compared. As much as possible, the current (2013) information is based on existing market research. The future trends assume ongoing improvements in technology based on historical trends and forecasts by market research organisations.

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[4] PUE is the Power Usage Effectiveness. This is a measure of the efficiency of the data centre given by the ratio of the total data centre energy consumption against the IT energy consumption.

4.3.1 Servers and IT equipment assumptions

The server is used as the basic unit of computing in this model. The computing capability of the server, like most electronics, has increased massively over time, doubling approximately every 18 months but it remains the basic modelling unit. The IT equipment is expected to continue to change as new technologies and innovations are made. For example, microservers are a more recent niche, which contain a very large number of low power CPUs. Further in the future, it is likely that the traditional integrated server with CPU, RAM and hard drive will become more disaggregated into separately installable and upgradable pieces of equipment. This is already available to some extent with blade servers housed in non-standardised blade enclosures, but will become more commonplace and compatible as more standardised network and interconnect technology is used. It is virtually impossible to predict what IT technologies and IT equipment that will be used in 2030, with ongoing research in traditional silicon electronics as well as organic, quantum and semiconductor technologies.

4.3.1.1 Number of servers

The number of servers in Australia in 2009 was estimated at 746 900 (Australian Computer Society, 2009)[5]. However, this used market research data which failed to account for custom servers which are not sold through normal channels. Experts estimate (based on modelling in UK and discussions with UK data centres) that typically an additional 10% of servers are custom designed. To account for the New Zealand data centre market, another 12% is added overall. This figure is based on the proportion of colocation data centres in Australia to New Zealand[6] and is considered a reasonable figure based on differences in the population and economy size. The estimate of 2013 server numbers uses a similar methodology to the ACS (2009) and updates it with 2012 Australia business statistics[7].

Table 2 shows the estimated number of servers in Australia and New Zealand. This includes all sizes of data centre, including under 10 kW. As a comparison, a single small data centre could house fewer than 50 servers while the largest data centres can house over 50,000. The number of servers in the US is estimated at approximately 10 million, and a few of the largest technology companies each have approaching 1 million servers across the globe[8].

Future growth is estimated at a 5% compound growth until 2015 (IDC, 2011)[9] before dropping to 3% growth. Previous projections in UK and USA have shown growth was greatly overestimated and therefore a more modest increase is predicted. This growth is driven by more demand in the way we currently use IT but also new ways of using IT such as the Internet of Things (IoT). The IoT comprises of an enormous number of small internet connected sensors in devices, businesses, and homes producing vast amounts of data to be stored and analysed in the data centre. While this is likely to demand huge amounts of computing and storage resource, it is expected to be offset to some degree by improvements in the server storage and computing power. However, it is recognised that future growth could be higher than 3%.

Table 2 Baseline scenario number of servers in Australia and New Zealand

Year	Number of servers in Australia and New Zealand
2009	900 000
2012	990 000
2015	1 090 000
2020	1 260 000
2025	1 460 000

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[5] http://www.computersite.com.au/assets/files/ACS_Computers_and_Carbon_Report.pdf
[6] http://www.datacentermap.com/datacenters.html
[7] http://www.abs.gov.au/AUSSTATS/abs@.nsf/ProductsbyTopic/514D970AA18B6DE0CA2577FF0011E061?OpenDocument
[8] http://www.microsoft.com/en-us/news/speeches/2013/07-08wpcballmer.aspx
[9] http://idg.com/www/pr.nsf/ByID/PKEY-8MAL69

4.3.1.2 Physical server power and virtualisation

The server runs continuously virtually 24 hours a day, 365 days a year and consumes energy. It is common for servers to run only one application and utilise very little of the available computing resource. Furthermore, the energy consumption of older servers did not vary greatly in response to the utilisation level.

However, a growing trend is the use of virtualisation, which allows many applications to run on the same physical server. The number of applications which are consolidated onto a single server is referred to as the virtualisation ratio. By virtualising, the available server resources are better utilised and more work is done per unit of energy consumed when compared to a non-virtualised server. A higher virtualisation ratio increases the utilisation rate further.

The efficiency of new servers has also improved, with power consumption matching the utilisation rate more closely. This can be seen in the higher power consumption of the virtualised server, which also tends to be more powerful, particularly in terms of available RAM and memory bandwidth.

The number of physical servers running virtualisation is estimated based on the ZDnet survey[10] in 2013. Projections were then made based on market research company IDC predictions for 2014[11] and Cisco projections of global virtualisation rates in 2017[12] and assumed to continue to increase to maximum of 55% in 2022. The virtualisation ratio is based on standard virtualisation using IDC categorisation. Based on this, the total ratio of virtual and cloud servers to physical servers is 3.2:1 in 2013.

The server power gives the average power consumption for a new server and is estimated from ENERGY STAR data[13] at 200W in 2013 for a non-virtualised server. This has fallen from approximately 250W in 2010 and it is assumed to fall more modestly at 5W every year until 2018 due to ongoing improvements in server component efficiency and design. No further improvements are projected beyond 2018 due to the uncertainty in making such predictions.

In addition, the ENERGY STAR server program in USA creates a further reduction of approximately 9% for over 75% of the market, until the rest of the market catches up approximately 3 years later. This cycle continues every 4 years. Due to the size of the USA market and because servers are technically identical across the world, this will also impact the Australian and New Zealand market.

The server power for virtualised servers is based on the increased utilisation as well as the higher computing power, particularly in terms of memory (RAM) and data bandwidth. This information is summarised in Table 3.

Table 3 Baseline scenario server virtualisation and power consumption

Year	New physical servers virtualised	New physical servers in cloud	Virtualisation ratio – standard virtualised	Virtualisation ratio - cloud	Approx. Utilisation	Server power (unvirtualised) (W)	Server power (virtualised)
2013	36%	21%	5:1	10:1	60%	200 W	512 W
2017	40%	25%	5:1	10:1	60%	168 W	461 W
2022	40%	30%	5:1	10:1	60%	163 W	466 W

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[10] http://www.zdnet.com/virtualization-reality-in-apac-7000018837/

[11] http://www.computerworld.com.au/article/408319/2012_year_big_data_/

[12] http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns1175/Cloud_Index_White_Paper.html

[13] http://www.energystar.gov/products/specs/node/142

4.3.1.3 Server lifetime

The server lifetime is the period of time it is actually used, rather than its technical or design lifetime. It is assumed to be 5 years, based on IDC figures in 2008. Since there is no set definition of lifetime, it is then corrected to fit the model. There is significant variation in the lifetime of the server, and it is common for servers to be refurbished and resold. Due to the improvement in efficiency and increases in processing capabilities, it can be sometimes most cost effective to replace servers every 18 months. Conversely smaller businesses with legacy applications and equipment may still be running servers older than seven years.

4.3.1.4 Total IT power and IT factor

The total IT power is calculated using the IT factor which represents the additional energy consumption for IT storage and networking equipment as a proportion of the server energy. It is calculated from the ENERGY STAR *Report to Congress on Server and Data Center Energy Efficiency Opportunities*[14] by calculating the proportion of total energy consumption by storage, and networking against the consumption by servers. While older projections had suggested that storage and networking would become a larger fraction of the total energy consumption due to the growth in data stored in the cloud, such as photos and other media, improvement in equipment efficiency as well as storage techniques have appeared to have largely offset this. Because of this and the lack of available data, the IT factor is not assumed to change. The IT factor is presented in Table 4.

Table 4 Baseline scenario IT factor

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2011 onwards	0%	38.9%	35.1%	35.1%

4.3.2 Data centre and data centre infrastructure assumptions

The number of data centres of each data centre type is used to allocate the server energy consumption proportionally across the data centre types. This enables modelling of different efficiencies based on data centre size and migration of data centre services to larger data centres and cloud providers.

4.3.2.1 Number of data centres

The number of data centres is based on a combination of DCD intelligence[15] and Gartner figures[16] for Australia and New Zealand in 2013, and Gartner projection for 2015. This shows that over 95% of data centres are small. Gartner projects that the number of data centres has already peaked and will start to fall despite growing demand for data centre services. Gartner states that this is due smaller data centres being consolidated into larger, more economical data centres. From 2015, this trend is assumed to continue with approximately 500 small data centres closing a year until 2019 when there are 42 000 small data centres. This corresponds with growth in Enterprise and Mega data centres which replace them.

This is summarised in Table 5.

Table 5 Baseline scenario number of data centres by size

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	42 000	950	150	15
2015	39 500	950	164	17

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[14] http://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf

[15] Nick Parfitt, DCD intelligence (29 Oct 2013) Where will the growth come from in Australasian datacentre markets? Presentation at DCD Converged Melbourne

[16] http://www.gartner.com/newsroom/id/1935317

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2020	37 000	995	199	21
2025	32 000	1 040	234	23

4.3.2.2 Data centre size and IT load capacity used

The data centre size is defined by the IT load power it can supply, measured in kW. This is calculated to match the DCD total data centre power, with a slow increase in power assumed for Enterprise and Mega data centres to 2023.

The utilisation is the fraction of the total available power that is actually being used by the IT equipment. Smaller data centres tend to be underutilised, and utilisation increases with size. The utilisation figures were chosen to align with the modelled IT equipment energy consumption.

Table 6 All scenarios data centre average IT load by data centre type

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	20 kW	200 kW	1 500 kW	3 000 kW
2015	20 kW	200 kW	1 560 kW	3 100 kW
2020	20 kW	200 kW	1 710 kW	3 350 kW
2025	20 kW	200 kW	1 800 kW	3 500 kW

Table 7 All scenarios percentage of IT load capacity used by data centre type

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	21%	35%	53%	70%
2015	23%	37%	55%	72%
2020	28%	42%	60%	77%
2025	33%	47%	65%	82%

4.3.2.3 Data Centre lifespan

The data centre lifespan is how long a data centre, including the major data centre infrastructure, is used for before being closed or undergoing a major retrofit of the infrastructure. This tends to be shorter than a normal building lifespan because the IT equipment it houses is changing quickly and has changing demands. Larger data centres have more stringent technical requirements and are therefore expected to be updated more quickly.

Table 8 Baseline scenario data centre lifespan

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	10 years	10 years	7 years	7 years

4.3.2.4 New data centre build rates

As the data centre reaches the end of its life, it can either be replaced by a new data centre or retrofitted. This variable gives the percentages that are replaced with new data centres, with the remaining assumed to be retrofitted. This figure is based on the market research from DCD Intelligence on the proportion of capital investment into retrofit and new data centres, which is adjusted for the difference in cost. It is assumed that a retrofit is a third of the cost of a new data centre and as a result is the preferred option for most data centres, in particular for small data centres with more limited resources. Mega data centres are assumed to have a much higher new build rate since this is still a new and growing class of data centres.

Table 9 Baseline scenario percentage of old data centres replaced by new data centres

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013 onwards	18%	20%	25%	60%

4.3.2.5 Average Data Centre PUE

The PUE measures the efficiency of the data centre infrastructure as a proportion of the IT equipment energy consumption. A PUE of two means that the data centre infrastructure consumes as much as the IT equipment and the total data centre energy consumption is double the IT equipment energy consumption. A lower PUE indicates higher efficiency, and a PUE of one means that the infrastructure consumes no energy. PUE is discussed in more detail in section 5.4.4.1.

Since the data centres operating in any given year are a mix of old and new with different PUEs, the average PUE calculates the data centres' PUE based on all the data centres still in use built over the preceding 10 or so years. The new and retrofit data centre PUE are adjusted to get an assumed average PUE of 2.5 for small and medium data centres in 2013, and an average of 2.2 for Enterprise data centres, based on the DRT Campos survey[17].

Since data centre lifetime is around ten years there is a legacy of old data centres built before 2010, when there was little to no interest in their energy efficiency. This means their average PUE in 2013 is still high but drops very rapidly over the next five years as they are replaced by new and retrofitted data centres with efficient designs and more efficient operations.

Table 10 Baseline scenario average data centre PUE

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	2.59	2.53	2.22	2.03
2015	2.50	2.40	2.06	1.82
2020	2.27	2.11	1.85	1.57
2025	2.15	1.98	1.73	1.51

4.3.2.6 New Data Centre PUE

Limitations in the operational efficiency as well as the technology and capital available mean that new small and medium data centres are less efficient than larger data centres. Although new data centres are being built with PUE of 1.1 and lower, these tend to be exceptional and a more modest PUE of 1.5 is assumed for mega data centres such as colocation data centres since they must also meet client requirements, falling to 1.4 in 2014.

Table 11 Baseline scenario new data centre PUE

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre

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[17] https://na6.salesforce.com/sfc/p/300000005uRq/a/80000000Cp9h/I9rUUKHYd7_JetkqnDggsPvX38qvTXDBfMZ79UFzMGc=

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	2.00	1.90	1.75	1.50
2015	2.00	1.80	1.60	1.40
2020	2.00	1.80	1.60	1.40
2025	2.00	1.80	1.60	1.40

4.3.2.7 Retrofit Data Centre PUE

Retrofit data centres are assumed to improve efficiency by approximately 10% based on the original design.

Table 12 Baseline scenario retrofit data centre PUE

Year	Small data centre	Medium data centre	Enterprise data centre	Mega data centre
2013	2.40	2.00	1.90	1.80
2015	2.20	2.00	1.90	1.80
2020	2.10	2.00	1.80	1.70
2025	2.10	2.00	1.70	1.50

4.4 Assumptions for Policy projection

The policy projection estimates the energy consumption and savings from implementing the suite of energy efficiency policies which are described and analysed in Section 5 of this report. This section describes how the policies are interpreted into quantitative changes.

4.4.1 Servers and IT equipment

4.4.1.1 Number of servers

The number of servers is calculated by the model based on the increase in virtualisation. Increasing the penetration of virtualisation and cloud servers results in an approximate 10% reduction in servers.

4.4.1.2 Physical server power and virtualisation

It is assumed that a range of new policies coming into effect increases the virtualisation range and virtualisation ratio modestly. These policies include guidance to promote financing for virtualisation, migration to cloud, and raising awareness.

- 2018 – Raising awareness, data centre services metric and data centre services rating increases work done in the cloud from 25% to 30% by 2021 with an equivalent reduction in small data centres.

Power consumption for servers is also reduced by approximately 5% due to more ambitious ENERGY STAR criteria and energy ratings.

- 2017 – new HEPS or comparative energy rating label increases efficiency by 7% for 75% of all servers. This falls to 0% efficiency improvement over four years as the market catches up. A second and third revision of the HEPS repeats this saving pattern.

4.4.2 Data centre and data centre infrastructure assumptions

4.4.2.1 Number of data centres

The number of small data centres is assumed to be falling under the baseline scenario and will be accelerated in the policy scenario through financial mechanisms, awareness raising, and development of cloud services.

This fall causes a rise in the larger data centres, with a net reduction in energy consumption of 80% for every small data centre that is closed.

4.4.2.2 Average Data Centre PUE

The average data centre PUE is the average of the new and retrofitted data centres built over the preceding 10 or so years.

4.4.2.3 New Data Centre PUE

The PUE for new data centres is impacted by a few policies:

- In 2016-2019 PUE is reduced by 0.01 for small and medium data centres due to higher efficiency UPS policies. This is based on a PUE improvement of 0.04 for the worst performing 25% of UPS.
- 2015 NABERS for Government set at NABERS 3 star, driving 10% of the enterprise data centre market to improve to PUE 1.55 (NABERS 4 star)
- 2019/2020 Government procurement for NABERS set at 4 star and mandatory disclosure for colocation driving 75% of enterprise market to achieve PUE 1.3 (NABERS 5 star)
- 2020 Building Codes set new data centre efficiency for small data centres minimum efficiency at 3 stars (PUE 1.8). For medium data centres, the efficiency is set at 4 stars (PUE1.55).

4.4.2.4 Retrofit Data Centre PUE

- In 2016-2019 PUE is reduced by 0.01 for retrofit small and medium data centres due to higher efficiency UPS policies. This is based on a 0.04% improvement for the worst performing 25% of UPS.
- 2015 NABERS for Government set at NABERS 3 star, driving 10% of the enterprise data centre market to improve to PUE 1.8 (NABERS 3 star) for retrofit data centres
- 2019/2020 Government procurement for NABERS set at 4 star and mandatory disclosure for colocation driving 75% of enterprise market to achieve PUE 1.55 (NABERS 4 star) for data centre retrofit.
- 2020 Building Codes set new data centre efficiency for small data centres this raises the PUE to 1.9 and for medium data centres, PUE 1.8.

4.5 Assumptions for policy and maximum technical savings projection

The maximum technical savings projections give an indication of the savings achievable through applying the best available technologies. This provides a second point of comparison for the policy line between what is projected to happen in the Baseline scenario and what can be saved. This section describes the assumptions made for comparison against the baseline scenario.

4.5.1 Servers and IT equipment

4.5.1.1 Number of servers

The number of servers falls in the model based on the increase in virtualisation. Very aggressive migration to cloud and virtualisation results in the server population almost halving.

4.5.1.2 Physical server power and virtualisation

In this scenario 80% of all physical servers are virtualised or in the cloud. Because a virtualised server does more work, approximately 90% of all work is performed in virtualised or cloud environments. This is based on VMware estimates[18] of the maximum possible level of virtualisation. In addition, the virtualisation ratio increases from 5:1 to 6:1, further reducing the number of servers required.

Server power is assumed to be about 65% of the baseline server power consumption based on highly-optimised server components, designs and configurations including the use of new server technologies wherever applicable.

4.5.1.3 Server lifetime

The server lifetime is reduced to 4 years to more rapidly adopt new energy saving servers.

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[18] http://www.serverwatch.com/server-news/vmware-ceo-aims-for-90-percent-server-virtualization.html

4.5.2 Data centre and data centre infrastructure assumptions

4.5.2.1 Number of data centres

The number of small data centres falls by around three quarters by 2025 with a corresponding increase in enterprise data centres. For every small data centre workload moved into a large data centre, the energy consumption is reduced to 10% of the original.

4.5.2.2 Data Centre lifespan

The lifespan is reduced for larger data centres through modular designs which apply the newest infrastructure and server technologies to maximise efficiency.

4.6 Current issues with the data and assumptions

There is currently a large difference between the calculated energy consumption of the IT equipment based on the data centre size when compared to estimates based on the number of servers. This is also reflected in the data centre energy consumption estimates by the Australian Computer Society (ACS) Report (4.5 TWh (16.2 PJ) in 2009), and Data Centre Dynamics (10TWh (36 PJ) in 2011). It is highly unlikely that the growth in data centres would account for this difference.

While the ACS report methodology more closely resembles the modelling used by Koomey for the US EPA (2009), the DCD Intelligence projection is better maintained and its energy projections for other countries including UK and US agrees with other models. Using population as a proxy for servers would suggest the ACS report is correct. However, based on GDP, the DCD intelligence projection is more in line with the UK and USA.

The model developed for this report is largely based on the number of servers, with corrections for custom server sales that are not accounted for through normal market channels.

4.7 Energy Projections

The total energy consumed by data centres in Australia and New Zealand in 2013 is calculated to be 8.2 TWh (29.5 PJ) and rising to 12.1 TWh (43.6 PJ) by 2030 (Figure 7). The rise is almost entirely the result of increasing demand for IT and increasing server energy consumption (

Figure 8) while the improving infrastructure efficiency is able to keep energy consumption approximately flat (Figure 9) despite increased heat load from the IT equipment.

The recommendations for the policy scenario are projected to limit the increase in energy consumption to 10.6 TWh (38.2 PJ) in 2030 which is a saving of 13%. From 2016 when the policies start coming into effect until around 2025, energy consumption does not rise. This is around a third of the impact compared to maximum savings scenario which reduces energy consumption by 35%.

Figure 7 Whole data centre energy projection in Australia and New Zealand

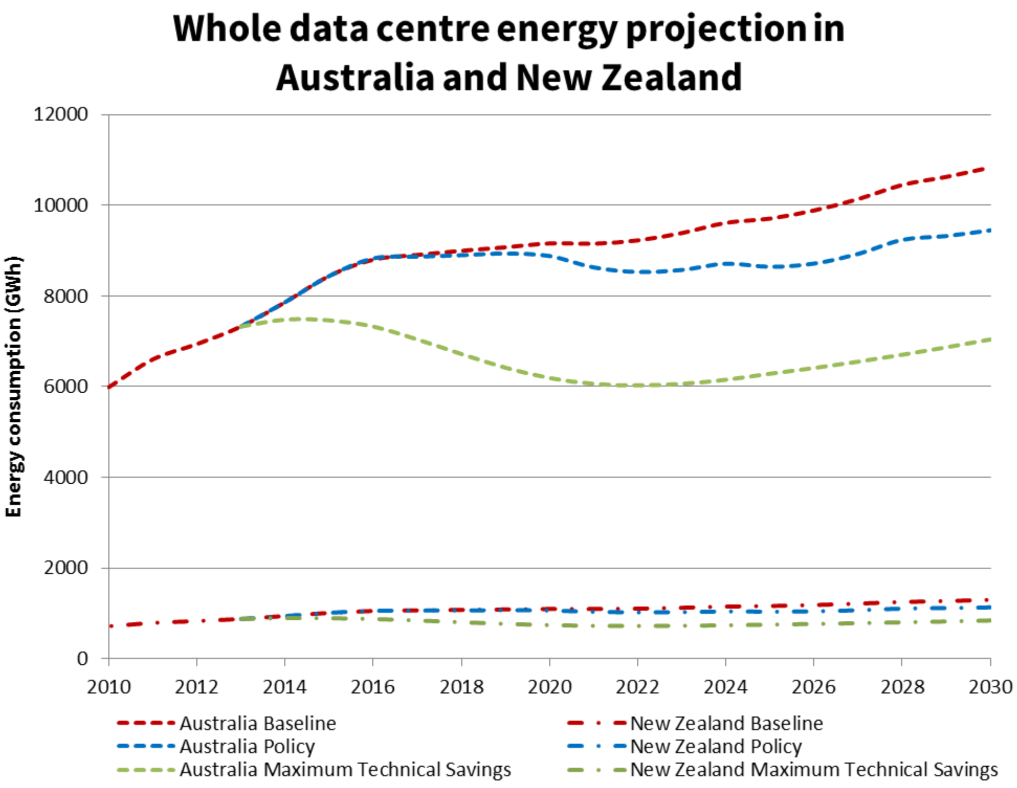


Figure 8 shows combined server energy consumption for data centres in Australia and New Zealand. The server energy consumption in the baseline rises fairly rapidly, doubling over the period 2010 to 2030.

The energy reduction in the maximum savings scenario is based on the number of servers in the cloud increasing from 25% to 40%. This reduces the number of physical servers by 26% in 2025. To achieve this in the policy scenario, it is recommended that a data centre services metric and label is developed for cloud services to raise awareness of savings. However, the low certainty that this will achieve the desired outcome means that a much more conservative estimate is made, with the number of cloud servers increasing from 25% to 30% in 2025. This means that only modest savings are projected.

Additional savings are made by introducing a comparative energy label or HEPS for servers and storage. However, these have limited savings potential because the products are commoditised and there are limited technical options to make improvements.

Energy from the data centre infrastructure is relatively flat as a result of improving PUE which started around 2009/2010 and will continue to have an impact over the longer lifetimes of the data centre. Since data centres have a lifetime of around 10 years and even those built as recently as 2008 have very poor efficiencies, it takes a long time to renew the entire stock. In addition, because retrofitting the data centre is much cheaper, many data centres choose this option to achieve more modest efficiency improvements. The maximum technical savings are able to reduce energy consumption by approximately 60% and this highlights how inefficient DC infrastructure and operations currently are. A large proportion of these savings also result from migrating to the cloud. This increases the proportion of more efficient mega and enterprise data centres which have higher efficiencies in general. However, as described earlier, a data centre services label designed to encourage greater use of cloud is estimated to only have limited effectiveness.

In the policy scenario, overall energy savings of approximately 11% are achieved by 2025. The savings are a result of strong adoption of NABERS data centre infrastructure rating within the enterprise and mega data centres, driving higher efficiency and saving a cumulative 3.5 TWh (12.6 PJ) by 2030. Building Codes would achieve a similar level of savings 3.4 TWh, (12.2 PJ) within the small and medium data centres. In addition, increased IT equipment efficiency contributes to approximately 2.1 TWh (7.6 PJ) of savings by 2030. Finally, encouraging more use of cloud computing creates 3.5 TWh (12.6 PJ) of cumulative savings by 2030.

Figure 8 Server energy projection in Australia and New Zealand

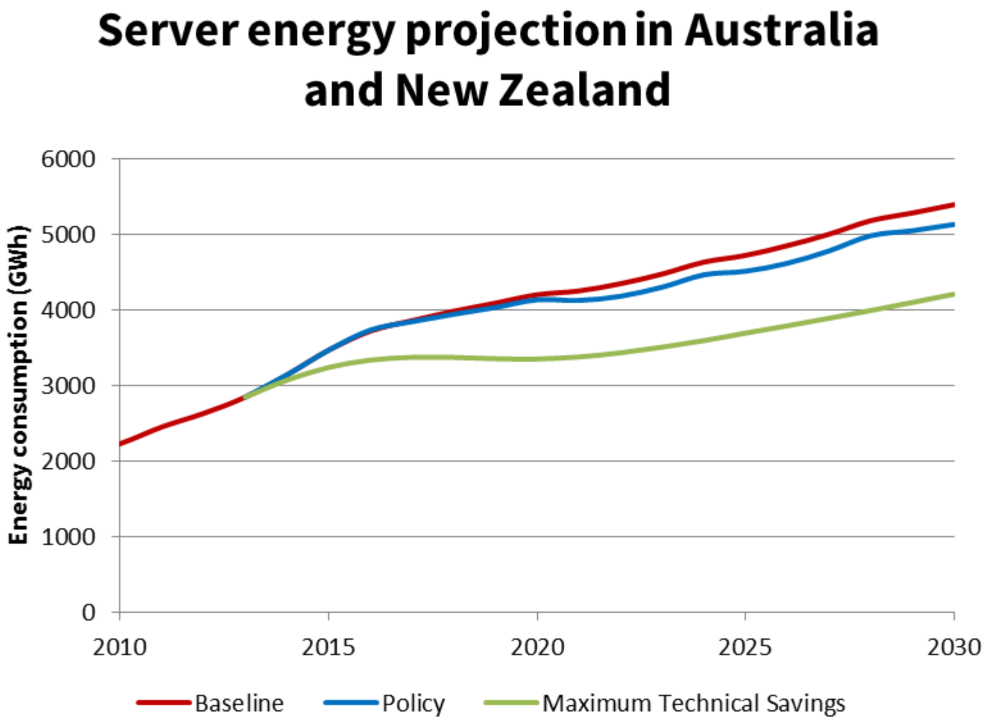
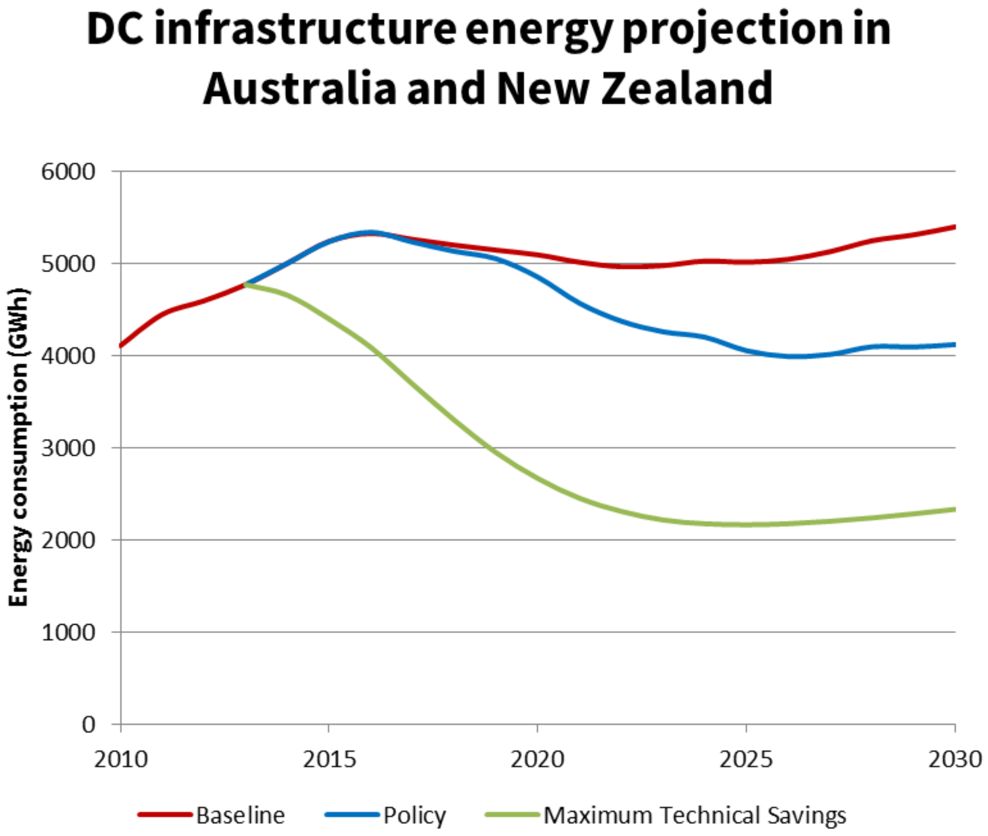


Figure 9 Data centre infrastructure energy projection in Australia and New Zealand



4.8 Policy sensitivity analysis

No quantitative policy sensitivity analysis was performed. However, the following observations can be made:

- The model is based on the number of servers, therefore energy consumption is directly proportional to this. For example, doubling the number of servers would double the energy consumption assuming no other variables are changed.
- IT product standards cover over 75% of the market as a result of intense competition. This means that small increases in the criteria ambition have a large overall effect.
- Mandatory Building Codes cover 100% of the small and medium market. This means that small changes in the criteria have a large overall effect.
- NABERS is dependent on the rate of adoption and the ability to influence the market. It is likely there is a tipping point which needs to be reached in terms of market adoption. It also depends more strongly on how much competition already exists within the market.
- Migrating to cloud computing has very large savings for each data centre closed but only a small proportion of the potential market is likely to be impacted. This means that it is very sensitive to the proportion of the market. This is responsible for the majority of the difference between the maximum technical savings and the policy line.

Because data centres have a long lifespan, the savings calculated over the period 2014-2030 do not account for the total impacts. In particular, Building Codes and mandatory disclosure of NABERS for the colocation market would only come into effect in 2020. Since the data centres will not all be replaced until around 2030, the energy savings would be made beyond 2030 and therefore, the data centre infrastructure policy savings are not fully accounted for.

4.9 Greenhouse gas emission projections

The carbon projections are made based on the average CO_2 intensity of electricity consumption in Australia and NZ. While there are a number of data centres using other fuel sources, there is insufficient information for a first order estimate. The carbon intensity is shown in Table 13 and it is assumed that this does not change in future.

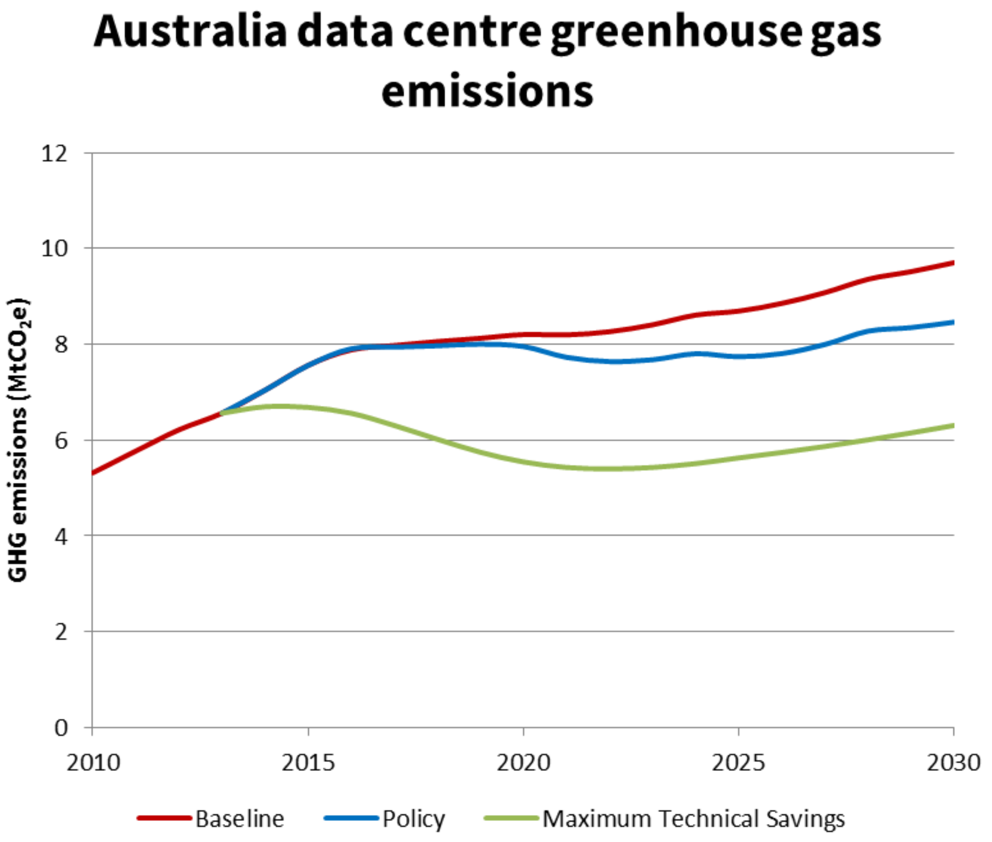
Table 13 Electricity carbon intensity

Year	Australia ($MtCO_2e/TWh$)	New Zealand ($MtCO_2e/TWh$)
2010	0.90	0.16
2011	0.88	0.15
2012 +	0.91	0.18

The data centre carbon emissions in Australia (

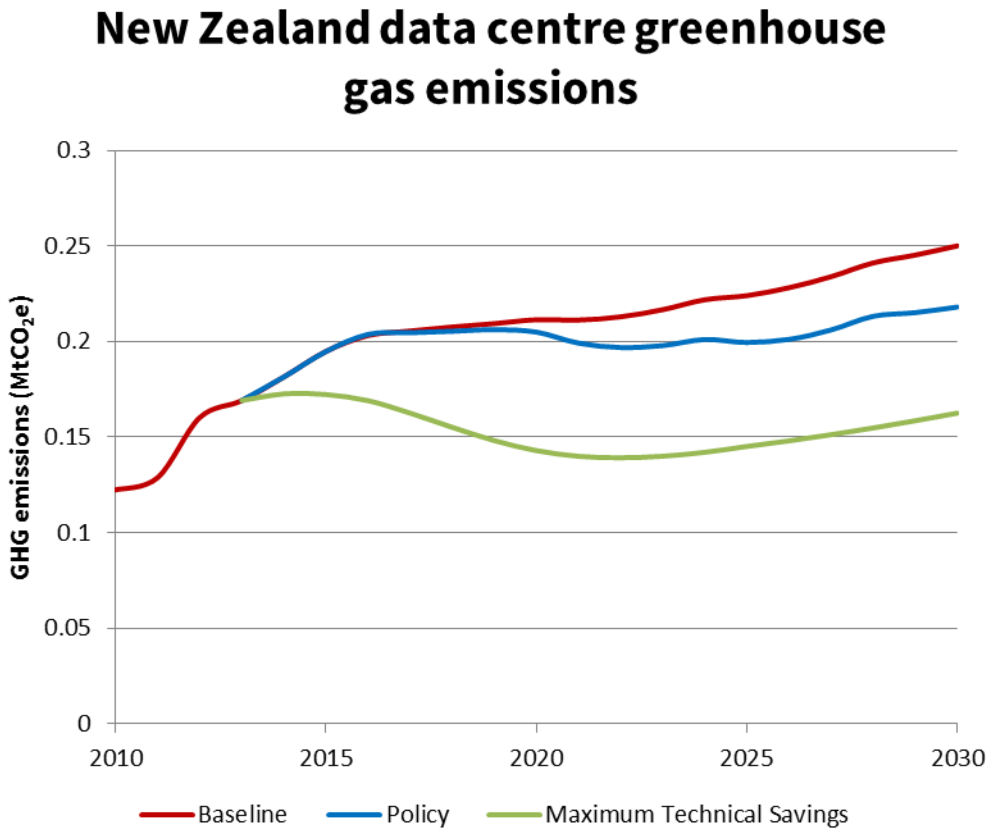
Figure 10) have the same overall pattern as the energy consumption since the carbon intensity is unchanged.

Figure 10 Greenhouse gas emissions from Australian data centres



Since there is a very high proportion of renewables in the NZ electricity mix, the carbon emissions arising from data centre use in New Zealand (Figure 11) is relatively low.

Figure 11 Greenhouse gas emissions from New Zealand data centres



4.10 Summary

The energy consumption for data centres is rising steadily. Under the baseline scenario, the rise will be tempered by improving efficiency across the data centre infrastructure, increasing use of virtualisation and more efficient IT equipment. However, there are substantial energy savings available, as shown by the best practice projections which more than halves the energy consumption compared to the baseline, and leads to an overall reduction in energy consumption compared to 2013.

Overall, the policies suggested are expected to have a strong impact on PUE, but has much more limited impact above the IT equipment shown in the data centre stack in Figure 1.

A more moderate policy scenario, which does not assume the maximum technical savings are attained, also suggests a drop of about 10% in energy consumption can be achieved. A large part of this is due to increasing the rate of virtualisation and migration of the least efficient small data centres to cloud services hosted in large data centres.

5. Opportunities to improve efficiency

5.1 Introduction

This section discusses policy approaches that could be applied to the Australian and New Zealand data centre market to improve energy efficiency and reduce carbon emissions. Since there are a very wide range of improvement options available from both a technical and policy perspective, it is important to prioritise actions based on the impacts they produce.

To do this, this section builds on the modelling and energy projections presented in the previous section. By building technically realistic scenarios based on the state of current technology, it is possible to see what energy savings can be achieved and over what timeframe, given realistic rates of data centre and IT equipment replacement. Since the model baseline energy projection already takes into account continued improvement and adoption of technology, it should not exaggerate possible savings and produce misleading policy incentives.

Building from the modelling and projections, this section looks at the technical savings that can realistically be achieved in the Australian and New Zealand data centre market.

5.2 Realistic technical savings

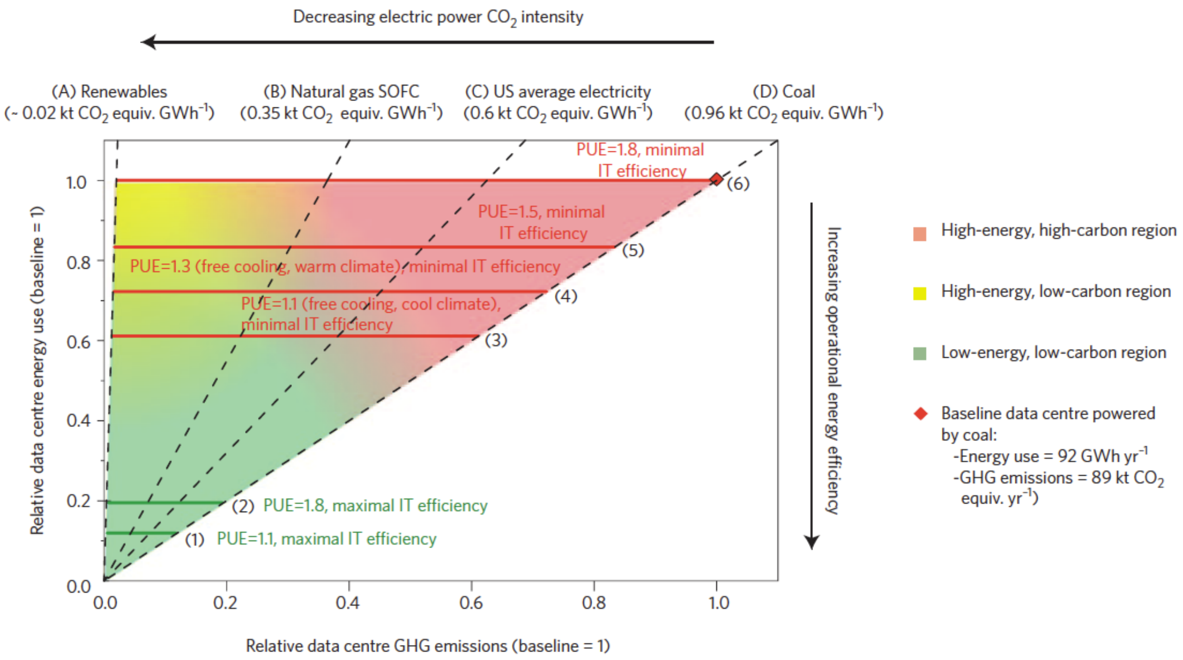
The technical savings are based on a very high level of efficiency being achieved across the market. This is based on the best technology now available being implemented across the data centre market, regardless of factors such as cost. This provides a point of comparison when comparing the policy proposals against what is known about what could be achieved.

However, to provide a useful point of comparison and target, some factors must be taken into consideration such as the normal replacement rate of equipment and datacentres. While it can be assumed that replacement rate increases, a total replacement in one year of all data centres and server equipment achieving efficiency levels demonstrated by companies such as Google, Facebook etc. is clearly not feasible.

Since the maximum technical savings will also never be achieved, the level at which ‘realistic’ is set is in some ways arbitrary and must rely on a large set of assumptions. These assumptions were detailed in Section 4.5.

The savings are split into a number of areas as shown in Figure 12. Energy consumption is reduced on the y-axis, while carbon emissions are reduced on the x-axis. Energy efficiency and renewables are therefore demonstrated as independent activities but both achieve overall carbon reduction. The key point is that without renewables the maximum carbon savings cannot be achieved through infrastructure improvements alone, and that IT efficiency (both equipment and software) accounts for half of the total possible efficiency improvements.

Figure 12 Data centre energy-carbon performance map (Koomey, 2013)[19]



5.2.1 Improving efficiency of the data centre infrastructure

The efficiency of the infrastructure is most commonly measured using the PUE metric. This can further be broken down into the parts as show in Figure 13. For an average data centre, the energy consumed is mainly in the mechanical cooling. The UPS represents the biggest consumption in the electrical side of infrastructure.

To cool the IT equipment, a cooling fluid (most likely air) must be provided to the server inlet at a suitable (lower) temperature and in sufficient volume. While both factors require energy, lowering the temperature requires more energy than increasing the volume. Inefficiency tends to occur as a result of the following factors (from largest to smallest):

- Over demand of cooling. The cool air may not be reaching the server equipment directly, either bypassing the equipment entirely or mixing with the hot air before reaching the server. Blocked or dirty air ducts and poor airflow design also means more power is required to ensure the air reaches the IT equipment. As a result, the air supply temperatures need to be set much lower than the target IT equipment inlet temperature.
- Equipment being operated inefficiently. The equipment's efficiency varies depending on what fraction of the total capacity is being utilised. The equipment is oversized compared to the actual IT heat load it removes. Redundant systems and underutilised data centre space only increase this problem. The optimal utilisation can depend on the type of equipment. For example, fans are more efficient when running slowly and below full capacity while compressors are most efficient at maximum capacity.
- Over provision of cooling. The amount of cooling may be over supplied as a result of the servers' inlet temperature target being set too low with poor, over sensitive controls overreacting to cooling demand.
- Inefficient equipment. This means that the energy consumption is high for each unit of cooling provided at a given utilisation level.

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[19] http://www.koomey.com/post/54013825367

Figure 13 Sankey Diagram for a PUE 2.0 data centre (Operational Intelligence, 2013)

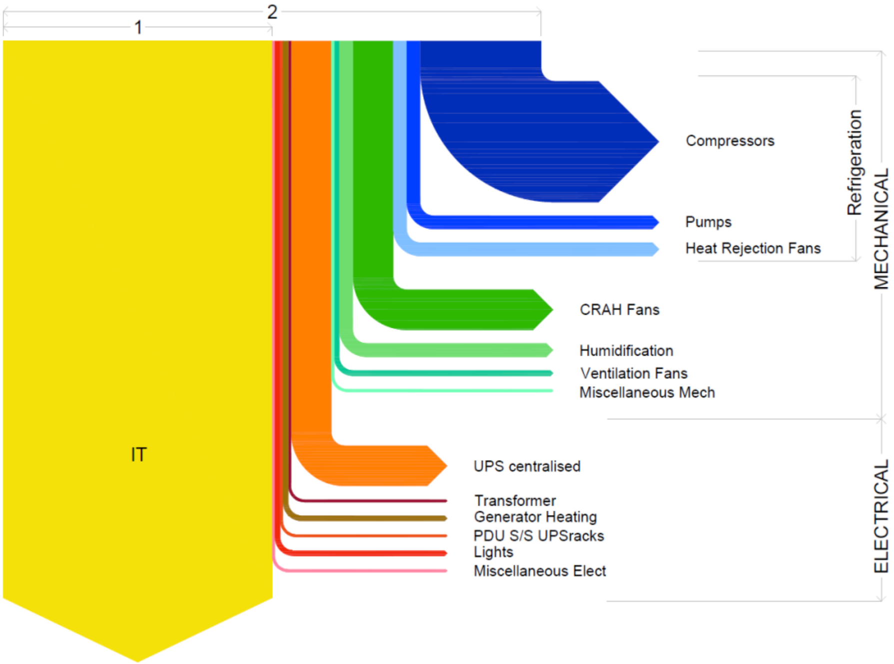
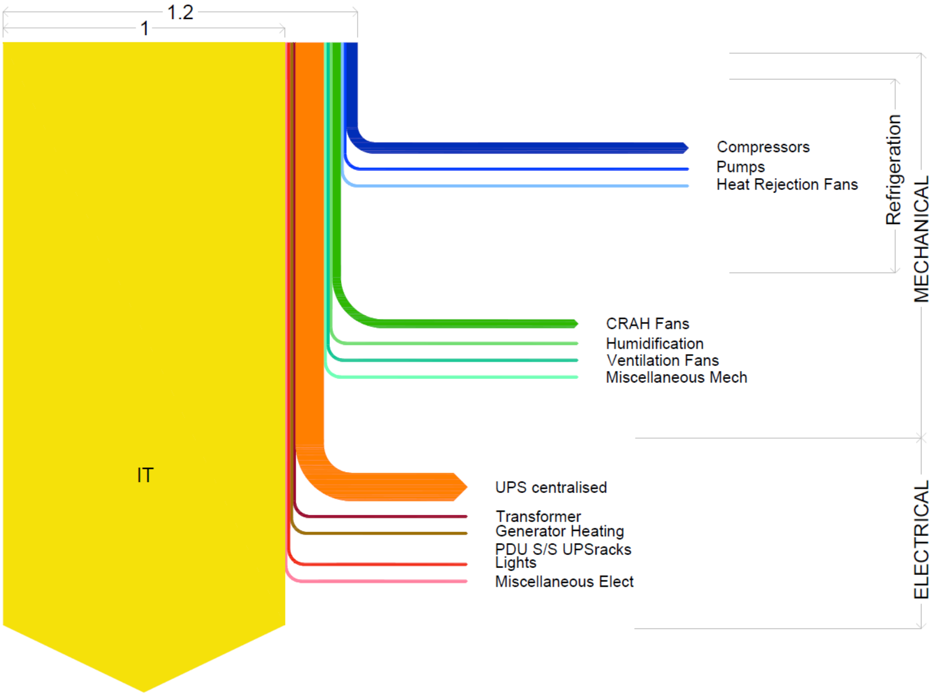


Figure 14 shows an idealised system achieving a PUE of 1.2. In this system, the biggest savings are unsurprisingly made in the systems with the largest consumption. However, this does not cover additional savings which may be achieved in the UPS.

Figure 14 Sankey Diagram for a PUE 1.2 data centre (Operational Intelligence, 2013)



While these static diagrams often suggest savings are made through good system design and high efficiency equipment, the savings are only realised through good management and planning to maximise equipment utilisation and operational best practice to maintain design efficiency. This is achieved with the following techniques:

- Isolating the cool supply air from the hot exhaust air and improving the airflow. This is achieved by installing physical barriers to prevent the air from mixing. The most basic form of this is to cover unused rack spaces with blanking panels and requires continuous management to ensure it is being done. Efficient data centres tend to go further and build corridors with walls and ceilings entirely isolating the hot server exhaust aisles from the cooler server inlet aisles. These practices do not increase efficiency themselves, but by doing so, the air supply temperature can be raised without affecting the server inlet temperature. This then reduces the compressor load which realises the energy savings.
- Using a modular approach that splits up the data centres into smaller rooms allows the infrastructure to be fitted and switched on as demand increases. Right sizing compressors to match the heat demand and running them in serial means that if on, each compressor runs at close to maximum capacity and efficiency. Running redundant fans in parallel ensures each fan runs at lower capacity and higher efficiency.
- Increasing the target server inlet temperature and increasing the allowable temperature range allows the supply air temperature to be raised and removes the requirement for aggressive temperature control.
- Selecting high efficiency equipment that is efficient over a wide utilisation range.

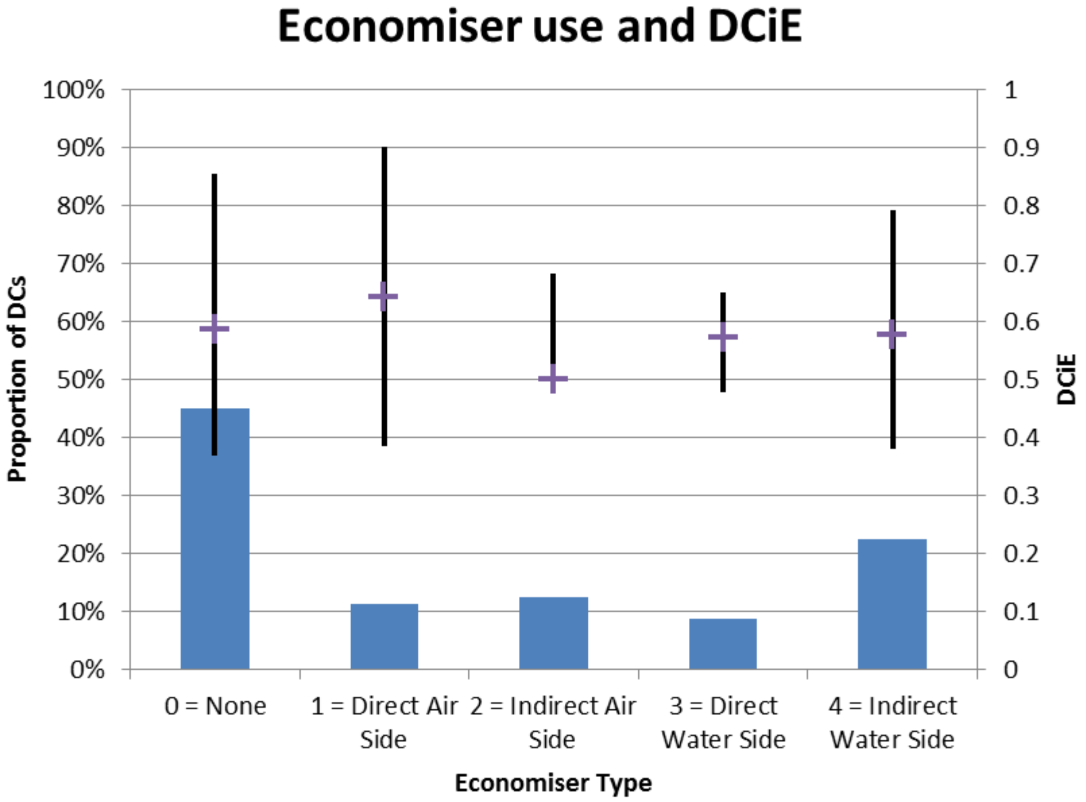
Rather than rely on mechanical compressor cooling there are a number of other techniques used which try to take advantage of the cooler outdoor environment. The most popular and common method is to use economisers which draw cool air directly from the outside into the data centre, through heat exchangers, or using adiabatic cooling. This removes the requirement to run the compressors except on very hot and humid days. Similarly water economisers use cool water from sources such as rivers or lakes.

Rear door heat exchangers supply cool water directly to the rear of the server rack and which then cools the hot air exhausting from the server directly at source. These are less widely used but can be more suitable where limited space results in high densities of equipment and in climates where economisers are not suitable.

While there are efficiency advantages, economisers tend to be more difficult to retrofit in restricted spaces while rear door heat exchangers requires additional infrastructure to supply the water cooling loops throughout the data centre. Furthermore, the total cost of ownership can be higher than mechanical compressors due to the additional equipment costs, even after taking energy savings into account.

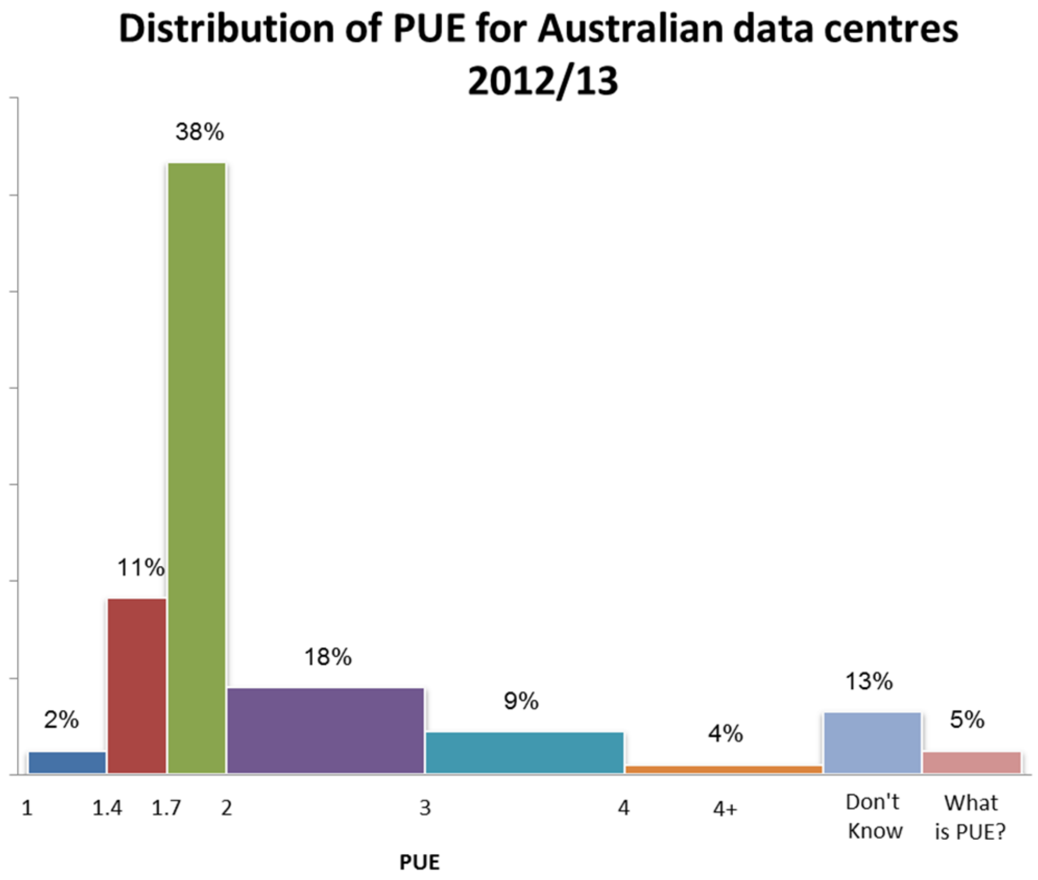
Figure 15 below shows a small dataset of 80 data centres participating in the EU Code of Conduct (CoC). The bar graph shows the proportion of data centres using each type of economiser, and the high-average-low plots show the range of efficiencies being achieved. The efficiency is measured in DCiE which is the inverse of PUE. The key points are that, within the CoC, just over half the participants used economisers. However, looking at the range of efficiencies, it shows efficiency is not necessarily substantially higher. This could be a result of poor operation, low utilisation of the data centre or poor design. Therefore a focus on the PUE to raise efficiency is more useful than requiring particular technical specifications.

Figure 15 Proportion of data centres using economiser cooling and PUE



The Campos survey[19] shows that current PUE for Enterprise and Mega data centres is relatively high although has improved substantially since 2011/12 (Figure 16). However, there is a relatively large tail of inefficient data centres as well as 18% who do not know or are unfamiliar with PUE. Furthermore, there is no information regarding the efficiency of small data centres.

Figure 16 Distribution of PUE for Australian data centres 2012/13 (DRT Campos Survey 2013)[20]



5.2.2 Improving efficiency of IT equipment

Savings in IT equipment can be divided into two broad areas; selection of high efficiency equipment with power management and maximising utilisation of equipment. Maximising utilisation can be achieved in a number of ways, most commonly through virtualisation/cloud but also careful configuration of the components such as selecting less powerful servers, including microservers[21]. As in the case with infrastructure, maximising utilisation can require changes to business practices and operation.

The use of virtualisation in Australia is already ahead of the worldwide average and expected to continue to grow under normal market forces. Accelerating this trend will likely achieve energy savings only over the short-medium term. However, virtualisation only achieves around 30-40% CPU utilisation, which means there is still opportunity to increase the density of the virtualisation i.e. place more services on one server and further increase the server utilisation.

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[20] https://na6.salesforce.com/sfc/p/300000005uRq/a/80000000Cp9h/I9rUUKHYd7_JetkqnDggsPvX38qvTXDBfMZ79UFzMGc=

[21] Microservers place many small independent nodes, around 50, consisting of a CPU and RAM into a server which normally houses 2 to 4 CPUs. Each node's processing capability is much more limited but is designed to perform this limited processing more energy efficiently.

5.2.3 Improving efficiency of software

Historically, efficiency was not a very important factor when developing software because the IT equipment computing capabilities had been increasing so fast. There are some exceptions, most notably smartphones, which have limited battery capacities. Energy efficient software is therefore currently a smaller area of interest, limited to research institutes and data centres operating near the cutting edge of technology. For data centres users, the software is often not developed by them but purchased or combined from existing modules and parts, making them reliant on the software developers to improve efficiency. It appears that a gap exists here as, unless specified, efficiency plays little or no role in software development unless the developer uses it to differentiate their product.

Application and system software are now often very complex and interlinked to provide additional functionality. This ability is one of the main advantages of IT and large scale data centre services. Improving the efficiency of the software is not achieved by using an additional application or service that can be applied on top of the existing application. Instead, it requires an analysis of all the software and the interactions to understand how much computing resource and energy are consumed by different parts of the software. It is then possible to redesign and re-engineer the software using program optimisation techniques to minimise the resource.

It is not entirely clear how efficient software can be, but it involves many different aspects which are currently being developed. Some solutions include:

- Improved metrics and profilers to determine the software efficiency during development
- Better software design and architecture.
- Smart compilers which are aware of the hardware capabilities and able to optimise themselves.
- Just in time compilers which dynamically optimise the application based on the input and other factors
- Aggregating and synchronising activities to maximise the time hardware can be put in low power states.

Software efficiency is more important for very large scale computing platforms, in particular the cloud where energy consumption has a very big impact on total operating costs and profit margins.

5.2.4 Interaction between Infrastructure, IT equipment and software

While the technical gains have been split into broad groups, there is significant interaction between data centre infrastructure, IT equipment and software. This means that dealing with each part in isolation will not bring the highest savings. However, optimising the whole system and all the interactions introduces trade-offs and raises the level of complexity. For example, the use of software resilience or virtualisation reduces the need for redundancy in the infrastructure. This may allow increased efficiency in the infrastructure but may be offset to some degree in the utilisation and efficiency within the IT equipment. A pragmatic approach is therefore needed and must consider the areas of responsibility, the level of capability and mutual understanding of each of the data centre groups.

Another significant interaction is the magnifying effect gained from increasing efficiency closer to the business process and application layers of the data centre stack. Each additional layer below the business process adds energy consumption - IT equipment is sized to run the software required by the business, which then requires data centre infrastructure. Therefore, by increasing the application efficiency, savings will also be achieved in the reduction of IT equipment and infrastructure or allowing the data centre to attract new clients to increase utilisation. Notably IT equipment efficiency can be improved relatively quickly, but due to the mechanical nature of infrastructure equipment equivalent reductions may not be achieved as quickly, resulting in a higher PUE, even though the data centre is consuming less overall energy. This also means that the savings described are not additive and there are diminishing returns for each additional efficiency improvement.

5.2.5 Renewables and energy reuse

In addition to efficiency gains, carbon reductions can be achieved by options such as:

- On site renewables
- Reuse of waste heat
- On site generation of electricity and cogeneration
- Off site renewables

Since the energy density of data centres is so high, it is often not practical to use traditional on-site renewables such as solar or wind to offset a significant proportion of the energy consumption. For example, to enable

Apple's data centre to use on site renewables, a 20MW solar array was installed covering the surrounding 40.5 ha (100 acres) of land[22]. Instead data centres, particularly in USA, are pursuing options such as fuel cells, and on site electricity generation (generally from gas) combined with trigeneration and district heating. These options can reduce the cost of electricity and reduce transmission losses through the electricity grid. A further benefit is resiliency, by generating electricity, the main grid can be used as a secondary backup feed, and removes the requirement for UPS and backup generators. These options tend to have impacts on town planning and other regulations and thus require very careful site selection and collaboration with the larger community (particularly in the case of trigeneration) to make use of the waste heat. Examples of trigeneration include the NAB data centre in Australia, and Helsinki, Finland which has a city wide district heating system through natural caves and tunnels providing an ideal site for data centres.

The trend for off-site renewables is being led by the Mega data centres that have the resources to invest tens and even hundreds of millions of dollars and commit to long term purchasing agreements of 10 or more years for entire wind farms. These have very poor payback unless electricity prices rise, in which case they have the added benefit of securing long term electricity prices and thus reducing business risk. However, this option is likely to be limited only to the largest data centre operators and is only considered after very high efficiency levels are achieved. The business models for companies currently investing in renewables are highly profitable and heavily dependent on IT to deliver their services. However, their profits are not derived from directly selling data centre services but relying on hardware sales, advertising and other services. The data centres themselves, though absolutely essential, are part of the larger commercial service ecosystem. In addition, many of these have very strong consumer brands and reputations. As a result the motivation to invest in renewables for a data centre service provider appears to be much lower e.g. for a data centre colocation operator whose profits are made leasing data centre space to other IT companies and have very low brand awareness by consumers and the general public.

Large scale energy purchasing is also very dependent on the local electricity market, which tends to be highly regulated and complex. A discussion of the electricity markets in Australia and New Zealand is moving beyond the scope of this project and will not be considered in depth as they vary in government and market ownership, market systems and pricing.

In the case of New Zealand, electricity generation was 75.5% renewable in September 2013 and a 90% national renewables target has been set for 2025. Although the proportion of renewable electricity is high in New Zealand, data centres are usually built a great distance from the hydro lakes which leads to transmission losses on the electricity grid.

5.3 Barriers and enablers

The other half of developing policy is to understand the barriers to implementation of the efficiency options. These barriers can be split into the following areas which are common to most energy efficiency activities but have characteristics unique to data centres.

5.3.1 Cost/Resource

This includes lack of capital, time, or being unable to make a winning business case over other priorities. Data centres are unique compared to other efficiency programs such as lighting, or HVAC because a process is being changed that has a direct impact on the business rather than an ancillary building service. This increases the perceived risk. The cost of some technologies that are being widely adopted can also be greater than the fractional returns being offered. For example, the use of free cooling still requires the capital cost of normal chillers for most data centres to maintain resiliency. This means that additional capital is required which may not be offset by the additional savings. However, in other cases, the savings are very high with returns within a few years. In these cases, obtaining a loan can be commercially viable.

The simplest way to reduce the up-front cost is through financial mechanisms such are loans, tax breaks and grants. There are a small number of financial mechanisms tied to improving efficiency in Australia and New Zealand including loans for efficient equipment. Internationally, new policies are attempting to place the financial burden on the energy utility suppliers, and trying to shift them to operate as Energy Service Companies. The costs are often then passed onto the consumer, although in theory the avoided unit cost of building new electricity generation capacity is greater than the unit cost of energy efficiency savings. In

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[22] http://www.apple.com/uk/environment/renewable-energy/

addition, banks are being encouraged to link loan conditions for projects to also include energy efficiency improvements.

Being able to present a compelling business case is also important to drive a project forward, and the ability to demonstrate benefits beyond increased efficiency, such as agility and improved resilience can be key to creating internal buy-in. Similarly, a loan application must provide the bank with a high level of confidence that the savings will be realised. This can be difficult when new and unfamiliar technologies must be assessed such as a virtualisation project.

5.3.2 Awareness and interest

Awareness that data centres consume significant energy is generally high, but is still not a factor for some data centre operators and their individual business cases. This is often the case where the data centre manager is not aware of the energy consumption since it is managed by another department. A number of data centres also do not directly measure energy consumption or PUE (Figure 16). For some data centres in mixed use office buildings, the cooling and power may not be isolated from the main building which means that efficiency and cost cannot be determined. Awareness, however, does appears to be increasingly rapidly, as shown by the DRT Campos survey[23].

Raising awareness through marketing, information disclosure and mandatory metering is an important starting point for building knowledge of market supply and demand, as well as measuring quantifiable efficiency improvements.

5.3.3 Knowledge and training

Knowledge and training enable better operational management and the application of new technologies and techniques. It is estimated that a 10% savings can be achieved through better operation with paybacks in less than a year.

Many inefficiencies within the data centre relate to poor operation and choice of equipment. Most commonly this occurs with oversized and overspecified infrastructure and IT equipment. This arises because of the risk associated with undersizing equipment which could result in failures and unresponsive data centre services. However, correct sizing of equipment and better operation generally improves the resilience and reduces the risk of human error, which is still the main cause of failure in the data centre.

Without sufficient training, knowledge and guidance it is not possible to act on the information provided by efficiency metrics.

5.3.4 Technology

Efficient technology is widely available, but selecting the most appropriate technology or suite of technologies can be difficult. New technologies also tend to be designed for larger data centres, and therefore smaller sized datacentres are sometimes unable to apply new, efficient technologies without investing in oversized and costly equipment. This in some ways has created a divide between the best data centres which are able to reduce PUE well below 1.3 and the rest of the data centre industry.

Many data centres owners often chose to retrofit the data centre rather build a new one. This also limits the technology options that can be applied since the space and location may not be suitable for economised cooling, increasing spaces for air flow and hot/cold aisle containment.

Technology in IT and in data centres also tends to change more rapidly than in other product areas, making it difficult to apply ‘normal’ policy tools which can quickly become obsolete. A useful yardstick is to measure the policy development process in terms of generations of new products. For example, new CPU generations are released approximately every 6 months. The time from the start of the development of the Computer Mandatory Minimum Energy Performance criteria under the EU Energy related Products Directive to it coming into force was around 4 years, or 8 generations of PC technology. This resulted in the efficiency targets and the product categorisations becoming less relevant. Policies must therefore be aware of the product being covered and speed at which technology changes. For the fastest moving products, in particular servers, policies may need to be more agile or have a mechanism that can account over time for increasing efficiency and changing products.

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[23] https://na6.salesforce.com/sfc/p/300000005uRq/a/80000000Cp9h/I9rUUKHYd7_JetkqnDggsPvX38qvTXDBfMZ79UFzMGc=

5.3.5 Outsourcing contracts

Due to the lack of resource, technology and training for smaller data centres, it may be more efficient to migrate to outsourced data centre or cloud services. However, migration is a complex process and can often be a very large proportion of costs sometimes equivalent to the cost of building or retrofitting a data centre.

5.4 Policies

Based on the discussion of the technologies and barriers, it is possible to characterise the policies by the issues they address, and ensure that prioritisation is given to the areas with greatest impact. The policy analysis covers the whole range of issues identified for every size of data centre. This approach is taken because a successful program often requires a suite of policies which address all the barriers to a greater or lesser degree, rather than focussing and solving single issues. It is recognised that responsibility for the various policies will cross a number of different Government Departments and will not entirely fall under the remit of the E3 Program.

The main focus will be on data centre policies which can set specific targets for improvement. These policies include product standards, data centre ratings, and building regulations. These have the advantage of raising awareness as well as creating supply and demand in the market.

Metrics and systems to measure the energy consumption and provide fair assessment between competing products and data centres are required to be in place before targets can be set.

The remaining policies address some of the specific barriers which may limit the impact of the targets and programs by providing finance, additional information and training. They also suggest possible strategies to improve efficiency where metrics and targets are not a suitable option, and can help set the long term future and direction of the market and efficiency targets. Except where indicated, the policies described in this report apply equally to the markets in Australia and New Zealand.

Table 14 Summary of current energy policies in effect in the Australian data centre market

	Infrastructure	**IT Equipment**	**Software**
Metrics	NABERS infrastructure (PUE) NABERS Whole data centre NSW Energy Saver	NABERS IT Equipment	
Product and DC standards, labels and ratings	NABERS infrastructure NABERS Whole data centre	NABERS IT Equipment	
Mandatory Minimum Energy Performance Standards (MEPS)			
Mandatory Metering, information disclosure			
Financial mechanisms	CEFC, NSW Energy Savings Scheme		
New technology, research			
Training			

5.4.1 Product efficiency standards

Efficient product standards can drive the market, in particular the manufacturers, to increase the efficiency of products.

Product standards come in a number of forms, including mandatory minimum efficiency performance standards (MEPS), mandatory comparative energy rating labels, and voluntary high efficiency performance standards (HEPS). These often include mandatory information disclosure and user operating advice which can create a small improvement in the operating efficiency.

Past experience from ENERGY STAR HEPS and ErP MEPS in Europe suggests that the current efficiency standards for IT equipment could be more ambitious, and this arises from the difficulty in projecting the efficiency improvements that can and will be made under normal market conditions and which are often based on past product performance. In the case of USA, MEPS are rarely introduced. This means that ENERGY STAR is the primary energy efficiency program for many products and it must partially fulfil the role of a MEPS as well as a HEPS, and affects the ambition of the efficiency criteria. In addition, providing a metric (see later section) based on the performance or functions of a product can be very difficult for a computer which is used for many different tasks and can be configured in many different ways.

Data centre equipment is not sold through normal consumer retail channels and therefore labels may not be seen by equipment purchasers in a normal retail environment. However, there are a large number of trade fairs and websites for which the information can be produced. Furthermore, most research suggests that the label does not directly influence the consumer to purchase high efficiency equipment. However, it is likely that the manufacturers respond to a mandatory label by improving efficiency when there is a highly competitive market and a lower rating presents a risk to their sales and brand.

Product efficiency standards are rarely able to guide the purchaser to choose the most appropriate hardware type and hardware configurations for a given purpose. This often causes more inefficiency than the hardware design and leads to over specified equipment or performance bottlenecks. In particular, as CPUs continue to get faster, more and faster memory is needed to ensure the CPU always has timely access to the data to process. Some specific workloads will also benefit from more specialised hardware such as microservers and graphics processing units (GPUs). Making the best choice therefore requires a good understanding of the intended server workload and the specific applications being run.

5.4.1.1 Uninterruptible Power Supplies (UPS)

The uninterruptible power supply (UPS) ensures the electricity reaching the IT equipment is free from damaging electrical distortions and disruptions. It is the single largest point of inefficiency in the data centre power infrastructure. Driven by international policies, the average efficiency of the UPS on the market has already improved greatly over the past few years. Current policies in effect include the voluntary EU Code of Conduct for AC Uninterruptible Power Supplies[24] and the ENERGY STAR UPSv1.0 specifications[25]. The efficiency difference between two new UPS is relatively small and the improvement over older UPS is large. This means the best opportunity occurs when older UPS are being replaced with a high efficiency product. It is estimated this will occur under normal business conditions over the next 4-6 years based on the age profile of the current data centres.

As an electrical component with relatively stable and mature technology there are fewer expected changes to design and functionality. As such, it is a suitable candidate for mandatory and voluntary product standards. Research and discussions to assess and recommend suitable policies are near completion in the EU through the EU Energy related Products Directive Preparatory Study[26]. The latest discussions at the time of writing this report were based on mandatory minimum efficiency standards set at the ENERGY STAR specification level although it is not clear whether this will be the final recommendation.

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[24] http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/ac-uninterruptible-power-systems

[25] http://www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies

[26] http://www.ecoups.org/

SWOT analysis: Standards and labelling for UPS	
Strengths Provides relatively high savings for a product standard. Well established standards and testing procedures exists from ENERGY STAR and EU Code of Conduct. The efficacy of minimum standards for EU Energy related Products Directive is already being investigated. Relatively static product technology and design with no major changes in function.	**Weaknesses** Choice of correct UPS and proper configuration is still required to ensure maximum savings. There are a number of different operational modes and alternative UPS technologies, with the least efficient also providing apparently better resiliency. As a result purchasers are often more conservative and choose higher resiliency, especially when there is no metering of the UPS energy loss and the bill is paid by a separate department. Voluntary standards require the buyer to be aware of and purchase higher efficiency products. A mandatory minimum does not. Technology seems to have reached near maximum efficiencies so may lead to only a short term saving of around 5 years.
Opportunities ENERGY STAR is already established within Australia and New Zealand, and extending to UPS could be relatively quick to implement compared to independently developing new specifications. UPS is well suited to financing schemes since they are expensive and have a long lifetime to accumulate savings. Combined with a label, this creates a simple eligibility process. Specifications can be implemented within Government procurement, using the label as one way to demonstrate eligibility.	**Threats** It can be more efficient to design a DC with no UPS. These however are not yet mainstream and demand for UPS will continue for at least the short-medium term. Super capacitors and per server UPS may be a more efficient option and an efficiency label excluding them may create a distorted market.

Recommendation

1. Introduce a voluntary high efficiency performance label for UPS based on ENERGY STAR – but only if it can be implemented within 2 years.
2. Introduce MEPS within 3-5 years to guarantee efficiency improvements in the market.

Estimated saving: 0.26 TWh (0.94 PJ)

Since the period of impact is predicted to be relatively short, a policy which can be implemented quickly is likely to create more savings. For New Zealand, this means ENERGY STAR could be more effective. However, since ENERGY STAR has low consumer awareness in Australia, any additional time required to implement a voluntary standard means it may not offset the lower market penetration. Therefore, a specification developed for mandatory minimum energy performance standard is needed to ensure future savings are not lost. ENERGY STAR and the EU ErP Preparatory Study recommendations could be used as the foundation to start development.

Government procurement criteria for UPS have not been recommended since very few UPS are directly procured so this is unlikely to have any measureable impact.

5.4.1.2 Servers

IT servers are the central piece of equipment in the data centre providing the IT services. Servers, like other types of computers have been improving rapidly in efficiency and processing power, driven by normal market forces as well as policies. The most well developed policy is currently ENERGY STAR and specification v2.0 came into effect in December 2013. At the time of writing an EU ErP Preparatory Study was in early stages of development, as well as EPEAT specifications which cover the life cycle environmental impacts. However, servers are considered to be a commoditised product and all source the same basic components from a limited number of manufacturers. This means the ways to improve efficiency and differentiate products tend to be more limited.

SWOT analysis: Standards and labelling for Servers	
Strengths	**Weaknesses**
ENERGY STAR already exists and version 2 has developed substantially from version 1 with lower idle power allowances, higher PSU efficiencies, and additional requirements. Investigations into energy performance standards are underway under the EU ErP Directive. EPEAT for servers is under development.	ENERGY STAR currently only raises efficiency on average 9% and it was estimated that 75% of servers already met the criteria before it came into effect. Its consultation process may not produce the optimal efficiency level in the specification. The process for development of a voluntary standard tends to be quite long, taking several generations of server. A mandatory standard would be even longer. Speculative efficiency standards based on expected efficiency are very hard to justify. Hard to qualify product families and ensure all configurations are efficient since configurations can vary so widely.
Opportunities	**Threats**
New SPEC[27] SERT metric is available and as a performance based metric could produce more useful results and higher standards. Possibility of working with manufacturers to supplement the label with best practice operation information for low volume server purchases by SMEs including operating temperatures and virtualisation benefits. Participation by E3 Program into the ENERGY STAR development process could improve outcomes and ambition. Comparative energy rating label can provide additional headroom to further differentiate product efficiency improvements especially for future server generations. However, the difference in performance over generations, may mean there is a wide gap between each band in the rating. A 6 star system designed to be effective for 4-5 years may therefore be unable to differentiate between models and configurations in the same generation.	More customised servers for different purposes e.g. microservers, storage servers etc. may make future metrics less meaningful. The results of the development of minimum energy performance standards for computers in the EU show that this may not be an effective policy option. The rapid improvements suggest that the current EU computer MEPs will have a small impact on the market. Using SPEC SERT to set criteria may require permission and licensing from SPEC. Limited ability to influence and revise the metric

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[27] SPEC – Standard Performance Evaluation Corporation

Recommendation

1. Develop either HEPS or comparative energy rating label for servers based on SPEC SERT metric for implementation around 2016-7.

Estimated saving: 1.7 TWh (6.1 PJ)

Because product development is fast and there is strong focus on efficiency improvements, a minimum standard is less likely to be effective. Therefore, high energy performance standards or a comparative energy rating label is recommended.

The new SPECpower and SPEC SERT metrics provide an opportunity for the next version of ENERGY STAR servers to be more ambitious than current specifications based on idle load power. The large amount of information being made available also means that a thorough analysis is possible, if the resources from participating stakeholders are available.

It is recommended that product standards for servers are introduced in Australia and New Zealand. These could be in effect by around 2016 if development starts in 2014. Development could start using participation in the meetings of the next ENERGY STAR specification in 2014-15 to inform the preferred policy route.

5.4.1.3 Data Storage

Data storage products cover a wide range of technologies, including the storage medium, the network connectivity and the management software. This impacts the functionality in terms of total storage capacity, data transfer bandwidth, data access speed and information management capabilities. The energy efficiency of storage equipment is dependent on how well it is optimised and therefore the effectiveness of the label is dependent on how clearly information about the functionality is provided.

This is a relatively new area for energy efficiency policy with only ENERGY STAR having developed specifications. However this was based on limited data. The EU ErP is also currently researching data storage alongside servers. It is likely that the specifications will undergo considerable changes as the policies mature. However, there is currently insufficient available data to recommend developing an independent standard.

Recommendation

1. Develop either a HEPS or comparative energy rating label for storage based on SNIA Emerald for implementation around 2018
2. Establish Government procurement criteria for storage equipment

Estimated saving: 0.4 TWh (1.4 PJ)

The lack of information means that no action can be made immediately. Instead it is recommended that the situation be reviewed annually and a determination then made. Given trends in other products, it is likely that a high energy performance label could start development in 2015-2016.

5.4.1.4 Other products

A number of other products were reviewed including networking equipment, chillers and PSUs.

- Networking equipment - there is insufficient information to determine what approaches and savings are possible for networking equipment.
- Chillers - these are a major component of the PUE metric and it is unlikely higher savings would result from the wide use of economisers.
- PSUs in servers and IT equipment are already efficient and the additional marginal savings beyond platinum are increasingly expensive. For products covered by a performance efficiency rating, this should be sufficient to ensure the best PSU to optimise cost and efficiency is installed. In 2013, 70% of data centre IT equipment PSUs registered with the 80plus program achieved platinum or titanium. 29% were gold rated and only 3% were silver. A realistic best case scenario for MEPS would be to set it at 80plus Platinum level, and that 30% of all IT equipment was impacted between 2016-2020, similar to the proportion of Gold and silver PSUs in 2013. The efficiency at best is raised by 3.3%, or 1% averaged over all IT equipment. This would result in less than 0.17 TWh (0.6 PJ) of cumulative energy savings by 2030.

5.4.2 Data centre audits and rating

National systems for labelling buildings are common. This is because the markets are national and cultural building styles and climate specific requirements create different priorities. Buildings are also rarely shipped to another country. The non-national exceptions are BREEAM and LEED, both of which have data centre specific criteria which are largely design standards.

Design standards, however, cannot predict the IT equipment and are therefore limited to PUE. In addition, since operation is a major cause of inefficiency, an operational rather than design metric is preferred although this can be a problem for new data centres.

Trends for modular, pre-fabricated designs however might create a global market for common data designs and, as a result, the use of common metrics may make it easier and cheaper to compare and qualify designs.

Audits can also be split into two main groups; advisory audits that include improvement opportunities assessment, and basic performance audits. In addition, newly created and emerging audit and certification schemes offer audits of the larger data centre performance, covering resilience, security and operational professionalism[28]. These are designed to provide the market with a quality standard of the overall service.

5.4.2.1 NABERS

NABERS is a voluntary energy rating and audit scheme for buildings in Australia while New Zealand has a similar scheme called NABERSNZ. In Australia it is managed by the NSW Government Office of Environment and Heritage (OEH), and EECA in New Zealand. NABERS covers a range of different building types, including offices, shopping centres, hotels, and now data centres. In Australia, three metrics, or tools were developed and introduced in 2013 for NABERS Data Centres which cover the DC infrastructure, the IT Equipment and the whole data centre. Currently the infrastructure and whole data centre ratings can only be applied to data centre infrastructures which are independent of the rest of a building. The metrics are discussed separately from the rating scheme in section 5.4.4.

Although NABERS is a voluntary scheme, under the Australian Building Energy Efficiency Disclosure Act, a NABERS Office rating is required for the sale and lease of office space exceeding 2000 square metres. Government office procurement policies also require NABERS ratings. A similar disclosure obligation creates a potential long term policy route for applying NABERS to data centres. This would apply only to the NABERS DC infrastructure rating (over a threshold in size) because it involves equipment that has similar functions to other buildings and relies on a proven metric and because this provides energy efficiency information to would-be clients.

It is not expected that mandatory disclosure or Government procurement targets will be set based on the IT equipment and/or Whole data centre rating. This is because the client is often responsible for the performance of the IT equipment and hence the rating. Additionally, the metric is at a different stage of development compared to PUE, and other technical factors within a data centre influencing efficiency means direct comparison between data centres is not yet as robust. However, it could be a useful system to measure and trend over time or alternatively there could be a national scheme developed with industry and supported by a professional trainers, assessment and auditors similar to CitySwitch for office tenants (see www.cityswitch.net.au).

SWOT analysis: NABERS for data centres	
Strengths NABERS exists and is well established in Australia and New Zealand for other building types. It has a complete program covering important aspects such as assessor training and accreditation. Data centre operators are already assessing their future obligations under this. It is an operational metric so takes into account how well a data centre is run in comparison to	**Weaknesses** The PUE is most relevant for colocation data centres and clients which represents only 21% of the market.

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[28] http://www.data-central.org/?page=Certifications

SWOT analysis: NABERS for data centres	
benchmarks. It has an established process for developing rules and alternative methods for measurements. This is important because every data centres tends to be unique with unexpected problems. NABERS Data Centre Infrastructure uses mature and well established PUE metric with detailed guidance on measurement.	
Opportunities The rules and methods developed can be used to complement the PUE standardisation work within ISO standards development committee. For new data centres, NABERS could provide guidance about how to assess the rating and market their predicted efficiency. Continue to establish and develop NABERS whole data centre and IT equipment voluntary ratings scheme Mandatory use of NABERS by Government or colocation can drive adoption Develop advisory audits alongside basic NABERS audits.	**Threats** NABERS Data Centres was launched in 2013 and the IT equipment uses a novel metric which has not been proven in the market. See Metrics and Measurements in Section 5.4.4.2. There is preference in some areas for more in depth advisory audits such as CEEDA. LEED, and to a lesser extent BREEAM, are international certification schemes. This means global organisations have a preference for these since they have greater international marketing and reputational value. However, they serve a distinctly different purpose (see Section 6.3.2). Experience with the EU Code of Conduct shows electricity consumption can be very commercially sensitive, particularly for cloud providers, since it provides in depth information about the business profitability and competitiveness. Total processing and storage capacity is likely more so. Some data centre may be unwilling to allow third parties to access energy consumption data and could result in resistance to any mandatory measures.

Recommendation

1. Establish Government procurement criteria for data centre infrastructure
2. Introduce procurement criteria for all data centre services based on data centre infrastructure
3. Introduce mandatory disclosure of data centre infrastructure for lease and sale of IT infrastructure services
4. Establish Government procurement criteria for whole data centres and IT equipment

For New Zealand it is recommended that NABERS infrastructure rating is first adopted.

Estimated savings: 3.5 TWh[29] (12.6 PJ)

NABERS is a key policy and provides a framework around which additional policies can develop and operate. To work successfully as a mandatory measure, the metric must be proven to be effective. This will occur through the current rule making system and as more information is obtained.

Adoption of NABERS Office rating has been driven strongly by Government procurement and it is expected this will also apply to data centres. Establishing criteria for procurement is therefore the key priority. Initially

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[29] Savings calculation based on Government target of 3 star in 2015, and 4 star in 2020.

this should only apply to procurement where the contractor has direct responsibility for the infrastructure, but could then be extended to all data centre services where the infrastructure may be subcontracted.

There are two competing factors to maximise savings through the Government target, firstly achieving direct energy savings in Government data centres, and secondly encouraging uptake of the ratings system in the market to drive wider disclosure and competition in the market. Setting a high, yet realistic, efficiency target guarantees some savings, but may discourage the majority of data centres to certify if demand for certification is limited to just Government contracts. It is possible to set a more modest target to reach a critical mass of data centres using the rating but this is not guaranteed. A two tier target is therefore suggested which is set a 3 star minimum and 4 star recommended (approximate PUE 1.55) in 2015 rising to 4 star minimum and 5 star recommended (approx. PUE 1.3) in 2020. The average PUE projected for enterprise data centres during that period is 2.05 in 2015 and 1.83 in 2020.

Looking to the examples of commercial office space, the next recommendation is to require disclosure of NABERS data centre infrastructure rating when leasing and selling, in a similar way to BEEC. The data centre infrastructure rating is more similar to the building services for offices and adapting or developing legislation for mandatory disclosure in line with BEEC has a higher chance of success. This would also apply to colocation only to avoid creating confusion in the market for other types of services. Since this requires a legislative amendment, the need to do this should be assessed against the current uptake of the ratings system.

Because the IT equipment and whole data centre metric is relatively unproven, it will require a longer time period to establish its accuracy, and could require new revisions. Therefore, mandatory measures are not expected to be possible or recommended until later when more data and feedback is available.

For New Zealand it is recommended that NABERS data centre infrastructure rating is adopted over the next few years to ensure long term benefits.

5.4.2.2 Data centre services label

A label for the data centre services provided by a data centre could inform clients and create competition in the market. Rather than using a metric to measure the efficiency of only the data centre hardware, it would provide an efficiency rating of the actual service being delivered. This gives the most relevant comparison for the client and gives the data centre the greatest flexibility when optimising the efficiency.

There are very few efficiency labels for services, since most policy has been focused on the product rather than the service being delivered. This means the development and implementation of the label will need further consideration. For example, the label cannot be physically attached to a service like a product although it can be provided in marketing materials. A voluntary label would allow such issues to be resolved more easily. In addition, appropriate metrics for data centre services are also still being developed. This means there is still some uncertainty about how achievable a label will be.

SWOT analysis: Data centre services label	
Strengths Covers the entire data centre infrastructure, IT equipment and software levels	**Weaknesses** Metrics may only apply to cloud services and be unable to compare against non-cloud options.
Opportunities Introduce a comparative energy rating label similar to products or NABERS	**Threats** There is no metric yet available and the development of a suitable metric may be significantly delayed Could be harmonised internationally especially since cloud services can be provided by data centres outside Australia and New Zealand

Recommendation

1. Develop a data centre rating label for introduction in 2020.

Estimated savings: 2.9 TWh (10.4 PJ)

5.4.3 Building Codes, local planning

Mandatory building regulations exist for data centres but treat them as commercial building space. This means that the efficiency requirements are based on human occupation and comfort levels with cooling systems optimised for much lower heat densities. Mandatory regulations can be very effective at raising the standards of the worst performing buildings, particularly for new buildings. Developing building regulations targeted specifically at data centres would enable the criteria to be optimised for the expected IT power densities. This would apply to the Infrastructure design only. The design stage of a data centre is also the best time to install energy metering. While the E3 is not responsible for building codes, other government agencies should be invited to consider these policies in the future.

SWOT analysis: Building codes	
Strengths Very clear requirements. Applies across the whole market.	**Weaknesses** Doesn't address poor operations. Doesn't address efficiency of IT and services. Any minimum standards will be exceeded by modern new large and mega data centres.
Opportunities Clarify where data centres are covered under current building regulations. Create regulations for new data centres (including change in use) based on the size of the data centre Set retrofit requirements for small-medium data centres. This can be set using technical design specifications, or a PUE target.	**Threats** Discourages some data centres from undertaking retrofits. Takes a long time to develop and enter into effect.

Recommendation

1. Develop mandatory data centre infrastructure efficiency targets for new small and medium data centres. Where a space was previously used for another function, this should be regarded as a new data centre.
2. Introduce minimum metering requirements within the regulations to enable accurate measurement of PUE.
3. Develop mandatory data centre efficiency targets for major retrofits.

Estimated savings: 3.4 TWh (12.2 PJ)

Building Codes are most relevant for small and medium data centres which do not have a strong business driver to improve efficiency. These also tend to be the most inefficient and there are a very large number of them. Mandatory regulations are therefore considered to be a justifiable intervention.

5.4.4 Metrics and measurement

Currently metrics in data centres are dominated by PUE. This is now a de facto standard and is in the process of becoming an ISO standard. However, the PUE is only a measure of the infrastructure and is mistakenly used as a measure of the whole data centre.

Development of other data centre metrics such as FVER (Fixed to Variable Energy Rating –see section 6.4.2) are being made, but are generally specific to a particular user, and should be used for monitoring internal progress rather than comparison between data centres. Due to the varied functions of data centres and IT, there has been a trend to attempt to produce metrics that can take into account everything. This has led to stalled development and complex metrics that can be very costly to implement.

A simple metric may be more useful. For example, automobile efficiency measured in km per litre does not take into account the car's loading capacity, acceleration or comfort. These additional features are left to the consumer to choose, and weigh against the basic efficiency. Listing all the features is clearly in the interest of the seller but requires a better informed customer. Similarly PUE does not take into account the resiliency of the data centre. It is expected that the customer can define the resiliency level and then minimise energy consumption by choosing the data centre with lowest PUE that meets the required resiliency.

5.4.4.1 PUE

PUE is a well-developed metric and widely understood and used. It measures the efficiency of the data centre infrastructure in terms of how much energy is used to supply power and cool the IT equipment. The PUE metric can be calculated as follows:

$$PUE = \frac{total\ data\ centre\ energy\ consumption}{IT\ equipment\ energy\ consumption}$$

The total data centre energy consumption is the sum of IT equipment and the data centre infrastructure. Therefore a perfect data centre infrastructure would require no energy and the PUE would be 1.

PUE is sometimes misinterpreted as an overall measure of data centre efficiency, however, it cannot determine how much productive work is being done by the IT equipment. It is therefore possible that a data centre with very efficient IT and software could consume less overall energy for a given task than a data centre with a very good PUE but very inefficient software. As a result, PUE is often criticised for disincentivising IT efficiency improvements since the PUE will get worse if the infrastructure energy consumption does not change. However, this is the correct behaviour for an infrastructure metric.

A second concern about PUE is the lack of transparency in the way in which PUE is measured. However, this is addressed both by NABERS and the ISO standard in development.

5.4.4.2 NABERS – whole data centre and IT equipment

This metric requires a count of every server core, CPU (central processing unit) speed and unformatted storage. The rating is then made by comparing actual consumption against an indicative median data centres energy consumption, that is a calculated by multiplying the total assessable processing and storage by conversion factors.

While the software will influence the server energy consumption and storage use, these metrics are largely focussed on the equipment design efficiency and how well it is operated. The amount of useful work, or the service provided is not a focus of the metric.

There are a few other metrics being developed internationally and each is different. Although metric discussions started in 2010 or earlier, this is still a relatively early stage of development and a variety of approaches are expected to emerge in the future.

SWOT analysis: NABERS IT equipment metric	
Strengths This is a simple and easy to understand metric, with few variables. It provides a good comparison against IT equipment being operated in the same way and of similar architectures.	**Weaknesses** The metric has been developed with industry based on statistical analysis of current data centres and IT equipment energy consumption. However, these are less likely to be efficiently operated and designed. From a technical analysis, future efficiency improvements based on virtualisation, high RAM server configurations, CPU architectures and software improvements may not be accurately reflected by the metric. This may mean it does not drive the desired behaviour.
Opportunities Metric could be refined to provide equivalency between CPU types and virtualisation/non-virtualised applications. A possible methodology could be similar to ODCA (Open Data Center Alliance see section 6.4.6) or Amazon which sells units of compute, although this is likely to be too complex. The development of SPEC SERT and detailed server performance metrics could mean this can be incorporated into the metric to create a more accurate revision in a few years. As more detailed metering and measurements in the data centre (see DCIM) become commonplace in the future, there are new opportunities to enhance the metric which do not place an unreasonable burden on the data centre. This metric can help inform the wider international development of IT and data centre metrics	**Threats** Other metrics such as a cloud services metric may limit the demand and requirement for a data centre hardware metric to a small niche.

Recommendation

1. Review the metric early, once sufficient data and feedback is available.

Energy saving: not known

The recommendations apply to the NSW OEH since they manage the NABERS program. The effectiveness of this metric will become clearer over time as it is implemented by other data centres. There is a possibility that the metric will need revising within 2-3 years. However, improvements in other metrics and measurements within the data centre means that more sophisticated metrics can be practically implemented.

5.4.4.3 DCIM – Data Centre Infrastructure Management

The difficulty in comparing efficiency between data centres and the lack of maturity in metrics means that in the short term it may be more important to promote better measurement of data centre energy consumption. This involves very granular measurements that allow energy consumption to be assigned to specific services or business functions. DCIM encompasses a wide range of measurements, which at their most sophisticated level, can provide these sorts of functions. This allows data centre operators and software developers to start to understand their impact on energy consumption.

<table>
<tr><th colspan="2">SWOT analysis: DCIM</th></tr>
<tr><td>Strengths
Allows internal measurement and optimisation at a business level.</td><td>Weaknesses
Expensive and can be disruptive to install, particularly to retrofit.</td></tr>
<tr><td>Opportunities
Can be included in procurement or similar contractual requirements e.g. “can your provider offer an energy consumption breakdown per user/service?”
Developing minimum requirements and functionality with standardised reporting for DCIM can help ensure a meaningful level of information is provided and interoperability between data centre infrastructure and IT equipment is maintained as equipment is replaced.
Some DCIM packages also include tools to manage IT utilisation etc.</td><td>Threats
May add cost and no benefit without the capability to analyse and interpret the data and to make improvements.
Some DCIM provides little more than basic PUE measurements which reflects poorly on the utility of DCIM.</td></tr>
</table>

Recommendations

1. Develop guidance discussing interoperability and minimum requirements for DCIM installations and procurement

   Energy Savings: none

Despite its benefits, this research has no policy recommendations to increase the use and granularity of the metering in data centres that can usefully combine with policies to improve operational efficiency. As such it is only recommended that guidance could be developed and disseminated for DCIM to help advise small and medium data centres who are interested in installing DCIM solutions. However, it is not expected to drive additional installations and as a metering system, no actual savings are projected.

5.4.4.4 Servers

The SPECpower metric and Server Energy Rating Tool[30] (SERT) have been under development for over 5 years, and a replacement is unlikely. This is a sophisticated and fully developed performance based metric which measures power and performance at different levels of hardware utilisation. A quicker revision of ENERGY STAR to Version 2.1 which makes use of this metric is planned. This will be a standard metric and should be adopted.

Current policies such as ENERGY STAR discourage consumption and performance to be modelled, instead requiring actual measurement of servers for a variety of configurations. Given the vast number of configurations and the cost of testing them all, a model or calculator may be more useful. For example, the idle energy consumption of the maximum configuration can be four times greater than the minimum configuration for one particular server model. Many server manufacturers have already developed such calculators, and therefore a process to validate the accuracy of the calculators may be more useful. This could include random testing of configurations for compliance and assurance.

5.4.4.5 Cloud services

There are efforts to develop metrics for cloud services such as the GHG protocol and Open Data Center Alliance (ODCA). While the GHG protocol is explicitly not intended for comparison across different providers, this is the stated aim of the ODCA[31]. The ODCA also benefits from some large Australian businesses including NAB being actively involved, and can help influence the direction in a manner suited to Australian business environment.

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[30] http://www.spec.org/power/

[31] http://www.opendatacenteralliance.org/docs/Carbon_Footprint_and_Energy_Efficiency_Rev2.0.pdf

Recommendations

1. Metrics for comparing cloud services should be developed as the first stage of reporting efficiency to consumers. It is estimated that this could be in place in 2017.

A metric should be simple and not overly emphasise every function. This should be left to the user to decide what is required. This should start with an investigation of the opportunities to use the ODCA model.

Another priority is to be absolutely clear what the metric needs to do. Previous developments have allowed the goalposts to move over time with different stakeholders having different perspectives - creating deadlock.

Allowing modelling of efficiency in servers and data centres is more useful in the long term than current processes. This could be achieved by specifying what the model must do, the required accuracy and detailing the processes for validation/independent assessment of the modelling. There are many models already available and a certification process is probably preferred to a Government developed standard model.

5.4.5 Government procurement and existing estate

Government procurement policies establish high efficiency standards and criteria to reduce energy consumption within the government estate as well as in contracted services. By basing the criteria on established labels and rating system, it is an effective means of driving market adoption of these labels since suppliers must comply to win a Government contract. In addition, the procurement policies and strategies are also adopted by some sectors particularly SMEs and Not-for-profits which lack the resources to assess and develop their own strategy.

The Australian Government already has a strong established energy efficiency strategy for data centres. Likewise, New Zealand also has a strong procurement strategy for IT. As such, future savings are already accounted for in the reference projection and it is unlikely that further savings can be achieved.

SWOT analysis: Government Procurement	
Strengths Government data centres (including local and state Government) are a relatively large proportion of the market representing 8.2% of the total data centre space (see section 3.6). Influences SME and Not-For-Profit industries.	**Weaknesses** It is much smaller than the telecom and finance industry (23%) which can exert greater influence and drive the market away from efficiency if other factors become more important. Procurement policies only apply to the Commonwealth Government sector, reducing the influence it can exert on the market.
Opportunities Provide more advice and make it easier to find. For example, through a centralised portal covering all aspects of data centre energy efficiency and Government activities, similar to Energy Efficiency Exchange[32]. Integrate UPS and server requirements through ENERGY STAR or similar High Efficiency Performance Standards. Adopt cloud first as an efficiency policy. Provide procurement advice or template contract energy efficiency sub-sections to counter bad procurement practices currently being applied such as specifying narrow temperature ranges instead of resilience. Encourage more adoption by local Government.	**Threats** None

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[32] http://eex.gov.au/

Recommendation

1. Create procurement criteria for servers and storage when labels are developed
2. Create procurement criteria for data centres under NABERS DC infrastructure rating
3. Require all eligible government data centres to report NABERS DC infrastructure rating
4. Create a portal for information specific to data centre energy efficiency, similar to or within the Energy Efficiency Exchange
5. Create procurement criteria for data centres under NABERS DC IT equipment and Whole data centre ratings

Energy savings: Savings are assigned to the program it supports

Since the Government policies are already strong, the additional benefits are derived from driving adoption of the labels and ensuring the information is easily accessible. This can be achieved by creating a centralised Government portal about energy efficiency, including all the policies listed in this report.

5.4.6 Financial, tax breaks, loans, penalties, carbon tax, ESCos

There are a few existing financial support mechanisms for energy efficiency in Australia and New Zealand, although fewer than available in Europe. These generally cover a limited range of different energy efficiency activities; including heating and cooling, motors and lighting some of which are closely related to the operation of data centre infrastructure. However, the specific requirements of a data centre’s improvements compared to an ancillary building service, such as those related to additional business risks, means that it could be valuable to approach the assessment differently.

One of the more significant and popular policies applied across Europe and USA is to place Energy Efficiency Obligations on Energy suppliers. This is only applied in a more limited way at a State level in Australia. This requires the energy supplier to demonstrate that a certain amount of additional energy efficiency improvements have been made as a result of energy supplier financial incentives and other interventions. This is designed to encourage suppliers to operate more like an Energy Service Company. It is clear that proposing such wide reaching policy is well beyond the scope of this project but it is noted that a national scheme was under consideration but the final outcome was unclear.

Any new financing mechanisms are unlikely, especially schemes requiring direct Government financing. However, existing schemes could be adapted to make them more beneficial. In particular, the limited range of activities available for financing means that the data centre may be unable to choose the most appropriate and cost effective option. This may already be underway in the shadow banking market with large IT companies offering interest free finance for purchasing and services. It may be useful to set some ground rules to ensure the terms of financing and the quality of the end services are regulated.

SWOT analysis: Financial mechanisms	
Strengths Financial support can help offset the large capital costs that may be involved.	**Weaknesses** Mechanisms such as the NSW Energy Saver which issue energy savings certificates are retrospective and do not help with high upfront capital costs. Poorly marketed and poorly targeted at data centres. It is difficult to demonstrate the effectiveness of efficiency improvements that are convincing and acceptable for public or private financing.
Opportunities Clarify in what sections data centres qualify under existing schemes (commercial buildings?). Provide data centre specific advice and guidance to existing financing schemes including the CEFC[33], Energy Efficiency Obligations and NZ EECA funding. This could include, for example, guidelines for assessing the energy efficiency of a virtualisation project which may be unfamiliar to auditors and assessors. Explicitly include UPS into the financing scheme. In addition, financing for cloud migration could eliminate some of the least efficient data centres, but would require sophisticated boundary setting to define the service and system being replaced. Harmonising the assessment process across the various financing schemes could also make financing easier to access. This has already been completed by The Green Grid covering virtualisation[34]. Market and advertise financing options to data centres and SMEs. Ensure financing can be applied to training since this has better payback and is necessary for long term savings.	**Threats** Paybacks may not be achieved in a constantly changing and expanding IT environment.

Recommendations

1. Provide additional guidance to finance schemes on how to assess and calculate energy efficiency savings in data centres for the various infrastructure, equipment and virtualisation savings.
2. Focus limited resources on SMEs which are less able to access commercial finance and capital.

Energy Savings: Savings are assigned to the program it supports

Providing clear guidance on the assessment of data centre efficiency improvements can improve the range of projects and reduce the risk for commercial loans as well as support direct finance mechanisms. In addition, these finance schemes could target SMEs more directly. For example State run programs such as the NSW

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[33] Clean Energy Finance Corporation

[34] http://www.thegreengrid.org/~/media/WhitePapers/Server%20Virtualization%20for%20Utilities_final.pdf?lang=en

Energy Saver scheme could place obligations on the energy utility supplier to achieve a proportion of the energy savings from the SME market.

5.4.7 Migration to cloud

Since the majority of data centres are small and inefficient, effectively targeting and improving every individual centre requires either a large workforce to implement the changes or it will take a very long time. This can be costly, inefficient, and difficult to effectively drive through policy. Instead, migrating to cloud or colocation services which have the scale and expertise to use the latest technologies is a better option. Since cloud is a high volume, low margin business it depends on high levels of efficiency and therefore can be relied on to deliver efficiency as an integral part of the business strategy. The fall in the projected number of data centres suggests that this is already occurring despite awareness of cloud computing still being very low.

SWOT analysis: Migration to cloud services	
Strengths Can deliver extremely high efficiency improvements, in the region of 80% energy savings. Large cloud providers have shown greater interest and resources to invest in renewables. Ties in closely with the Australian National Cloud Computing Strategy.[35]	**Weaknesses** There are many other challenges, such as data security, which makes migration complex and can be high risk. Migration can be very costly. SMEs awareness of cloud computing is very low according to the National Cloud Computing Strategy.
Opportunities Establish working relationship with the National Standing Committee for Cloud Computing. Identify complementary goals and actions. This can also deliver many other aspects of policy including IT skills, research, security and regulation. Raise awareness of cloud and its efficiency advantages.	**Threats** Cloud providers optimise for Total Cost of Ownership rather than energy efficiency. These may start to diverge as technology and related costs change. SME IT professionals have little incentive to promote cloud services since this could threaten their own employment niche. Large/mega data centres in large cities could strain the electricity grid. Energy savings within the data centre may be offset by increased energy consumption from increasing internet traffic to remote cloud data centres.

Recommendations

1. Increase awareness within small businesses of cloud computing and its benefits, including energy efficiency. In Australia, this could be coordinated with the activities of the National Cloud Computing Strategy.
2. Within New Zealand, the Code for Cloud computing can be adapted to include efficiency commitments, and eventually efficiency disclosure.

Because awareness is currently low, increasing awareness is projected to have a measureable impact. This is combined with other supporting policies such as financial mechanisms to offset the cost, the development of data centre services metrics and ratings to create a stronger market for cloud services.

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[35] http://www.communications.gov.au/digital_economy/cloud_computing

5.4.8 CPD, training and recognised competent personnel

A skills gap for data centre engineers has been identified as a key problem within the European data centre industry. A small number of schemes are in place, mostly originating in the UK, to provide energy efficiency training for data centre professionals, but their effectiveness is not clear. In addition, the EU is currently funding a 1.7 million Euro research project, the PAN European Data Centre Academy[36], to establish a training and research action plan for the data centre industry which includes energy efficiency. No information on energy efficient data centre training in Australia was identified in the research.

SWOT analysis: Training	
Strengths Training and operational improvements generally yield 10% savings with paybacks less than a year for infrastructure improvements. They can provide the basis of ongoing improvements and energy and environmental management systems. It maximises the effectiveness of other policies such as product standards by enabling the purchaser to specify and configure hardware effectively.	**Weaknesses** Difficult to quantify outcomes and benefits from training. Constantly changing technology can require re-training at additional cost.
Opportunities Encourage/fund research to establish what training is required for next generation of data centre professionals. Assess current training schemes and bodies such as the BCS Green IT certification. Develop training with professional bodies. Integrate with the National Cloud Computing Strategy. Develop recognised certification for engineers.	**Threats** Training seems to be undervalued by the market. Difficultly engaging stakeholders suggest this could be hard to establish.

Recommendations

1. Assess interest and cost of conducting research in the area, for example through open calls for tender and engagement with universities.

   Energy savings: not possible to establish at this early stage.

The long term value of training means that future efforts are recommended in this area. However, the lack of data means that it is only possible to recommend further research at this stage. This could be integrated with the Cloud Computing Strategy in Australia since research is a part of the strategy.

5.4.9 Research

Technology based industries already invest heavily into research as the markets are often driven by innovation to create new demand. Research therefore creates new business markets and creates skills and jobs. While the USA has the largest research base, both academically and commercially, research projects in energy efficiency are also gaining momentum in Europe, particularly Germany, Netherlands and UK. The German National Energy Efficiency Plan is highlighted by the Enabling Technology report (Thomond, 2013) for its funding initiatives which stimulate all stages of technology diffusion from research to widespread adoption. The UK Government has also identified big data and energy efficient computing as one of the eight great technologies which will drive the UK economy, and has committed 189 million pounds for research, equivalent to approximately 13% of the national research budget[37].

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[36] http://www.data-central.org/page/micrositehome/

[37] https://www.gov.uk/government/news/600-million-investment-in-the-eight-great-technologies

SWOT analysis: Research	
Strengths Could help establish the next generation of energy efficiency particularly in software. Can create new businesses and innovations through technology transfer.	**Weaknesses** Higher risk. Efficiency gains may not be realised for a long time.
Opportunities Establish funding and grants targeted at IT energy efficiency with suitable assessment criteria for grant allocation. Conduct research into skills and training requirements. Conduct research into energy efficient software and development techniques. Could be integrated with the Australia National Cloud Computing Strategy	**Threats** Could be out-competed by commercial research with greater resources.

Recommendations - none

Note: Setting national research priorities, budgets and strategies for research is beyond the scope of this report. However, research is an element included in the Australia National Cloud Computing Strategy, and energy efficiency could play a role in this.

5.5 Policy summary

The analysis in section 5.4 results in a wide range of recommendations with a mixture of different policies impacting different parts of the data centre stack. These are summarised in Table 15.

Table 15 Summary of policies and recommendations

Policy name	Policy type	Recommendations	Impact area
NABERS data centre infrastructure	Metrics	None	Data centre infrastructure
NABERS data centre infrastructure	Voluntary rating label	Adopt rating system in New Zealand	Data centre infrastructure
NABERS IT equipment, whole data centre	Metrics	Review metric annually and revise as necessary	IT equipment, DC infrastructure
NABERS IT equipment, whole data centre	Voluntary rating label	None	IT equipment, DC infrastructure
SPEC SERT	Metric	Adopt for HEPS/rating label	IT servers
SNIA Emerald Program	Metric	Adopt for HEPS/rating label	IT storage
Data centre service metric	Metric	Develop metrics with industry	Whole data centre
Data centre service	Voluntary	Introduce rating label	Whole data

Policy name	Policy type	Recommendations	Impact area
label	rating label		centre
Building Codes	Mandatory MEPS	Develop MEPS for new and retrofit data centres, targeting small and medium data centres	DC infrastructure
Building Codes	Metering	Mandatory metering for NABERS data centre infrastructure	DC infrastructure
BEEC	information disclosure	Mandatory information disclosure for colocation lease and sale	DC infrastructure
ENERGY STAR	HEPS	Develop IT server HEPS Develop IT storage HEPS	IT servers IT storage
Comparative energy rating label	Mandatory rating label	Develop IT server HEPS Develop IT storage HEPS	IT servers IT storage
GEMS	Mandatory MEPS	Develop UPS MEPS	UPS
Cloud migration	Information	Increase awareness by SMEs	Whole data centre
Government Procurement	Procurement	Create procurement criteria for servers and storage Create procurement criteria for data centres infrastructure Require government data centres to report NABERS rating Create a portal collating information for data centre specific energy saving policies and advice	IT servers IT storage DC infrastructure
Financial mechanisms	Financial mechanisms	Develop guidance to assess and calculate savings from energy efficiency investments Encourage that limited resources for financial mechanisms are focused on SMEs	Whole data centre
Research	Research	Encourage research within National Cloud Computing Strategy	Whole data centre
Training	Training	Encourage training research within National Cloud Computing Strategy	Whole data centre

Overall, in terms of policy types, ratings label and standards are the most likely to drive improvements in infrastructure and in IT equipment.

5.5.1 Data centre infrastructure

Based on the current situation for data centres, targeting savings in the infrastructure will have the greatest impact and is where most savings are being made in the reference projection. It is clear that the central data centre policy that can drive this further in the short to medium term is the NABERS data centre infrastructure rating. Since this is based on a more mature metric and data centre infrastructure unlikely to change rapidly, it is possible to build other support policies which can drive adoption. In addition, NABERS is the only core policy which addresses operational efficiency.

Past experience shows that using NABERS for Government procurement is a key way to encourage adoption in the market. If necessary, this can also be supported by legislation to require mandatory disclosure of NABERS ratings for lease of colocation space.

The increased adoption and competition is then expected to create a stronger business case for improvements in new and retrofitted data centres. At this point it is important that other barriers are addressed by helping to provide access to finance, information, advice and training. While policies may not directly address the barriers, they can make it easier to find the necessary services through a centralised point of information. In addition, guidance covering a range of issues can help address some of the shortcomings of existing policies when applied to data centres:

- Advisory audits linked to NABERS rating help establish the competitive advantage and business case
- Guidance to assess energy savings helps increase confidence in return on investments for loans or internal financing

A possible limitation of NABERS is that smaller data centres are unlikely to be leased or sold and even under mandatory measures an exemption may still be necessary. Without another strong market driver, mandatory measures are justified. This should include the installation of metering, and Building Codes for retrofits and new constructions. In addition, existing finance mechanisms which provide direct funding could focus on SMEs as they have more limited access to commercial loans. Again, this can be based on guidance to assess energy savings.

5.5.2 IT equipment and UPS

For IT equipment, product standards based on design efficiency such as labels and ENERGY STAR are the recommended policy tool. The NABERS IT equipment rating is not designed for selecting and purchasing IT equipment but can provide DC operators with useful information about operational efficiency when used in combination with additional data. In particular, servers are the largest IT energy consumers and a HEPS or rating label is recommended. The finalisation of the SPEC SERT metric also means that the criteria can be based on the performance of the server which provides a fair assessment over different server configurations, generations, and types. While a mandatory rating label is more effective, adoption of a voluntary HEPS can also be driven with Government procurement criteria. Labels for IT storage can similarly be developed.

UPS are not changing as quickly as IT equipment and because a product standard is relatively easy to implement, a MEPS or HEPS is recommended to ensure the worst products on the market are not sold.

5.5.3 Migrating to cloud

The economies of scale and competition in cloud computing mean that efficiency is expected to always be higher than small and medium data centres. Migrating to the cloud in theory offers very large savings. Although there are currently limited policy options that could effectively drive this there are synergies with the Australia National Cloud Computing Strategy which aims to increase use of the cloud, particularly with SMEs. Since this is already happening despite awareness still being low, a simple policy to increase awareness could drive measurable adoption and create the market demand for a voluntary rating system which compares the efficiency of data centre services. This is obviously dependent on a suitable metric which could be developed in collaboration with industry, such as the ODCA.

5.5.4 Research and training

Skills and training often remains an issue for large energy efficiency programs, and is poorly addressed by policy. The policies to establish professional training for data centre engineers and long term research mainly serves to describe activities in other regions and is stretching the scope and influence of this report. Again, however, there are potentially strong relationships with the Australia National Cloud Computing Strategy and an opportunity to encourage energy efficiency to be integrated within this should be considered. For New

Zealand, there are also ties with the New Zealand IITP Code for Cloud Computing to establish energy efficiency ratings. However, the policies for training and research must be considered with respect to wider national economic priorities.

6. International Programs

6.1 Introduction

There are only a limited number of data centre energy efficiency programs with a truly global remit. However, a number of national activities, particularly from the US have a strong international influence. This is to be expected given the current size and global dominance of the US IT industry.

The section covers the main international programs, and some of the national programs with a strong data centre and energy efficiency aspect to them. It provides a basic understanding of their role and aims to highlight opportunities for collaboration or harmonisation. A large number of these schemes have already been mentioned in the previous section with related recommendations and these will be reiterated briefly.

The current schemes can be divided in line with the policies discussed in Section 5.4:

- Product efficiency standards
- Data centre audits and rating.
- Metrics and measurements.
- Data centre operational guidance and training.

6.2 Product Efficiency standards

Product standards refer to IT and other equipment within the data centre. As a mature policy area, with strong policy development processes, such standards can be more easily assessed and adopted or harmonised.

6.2.1 EU Energy Related Products Directive for UPS and Enterprise Servers

- Geography: EU
- Current size: Currently only at early research (Preparatory study) stage, PSU requirements for servers are covered under the ErP implementing measure for computers
- What it aims to achieve: Assess and set efficiency policy, MEPs, labels or voluntary agreement (VA) as appropriate to raise product efficiency
- Administrative body: EC
- Website: http://www.ecoups.org/, http://www.ecodesign-servers.eu/

This research should be reviewed at the end its development project and a decision made based on the recommendations and future intentions of the EC to introduce regulations.

The ErP implementing measure for computers specified minimum performance standards for PSUs but the estimated savings were negligible.

6.2.2 ENERGY STAR for Enterprise Servers, Enterprise Storage, UPS

- Geography: USA. Servers are expected to be included in the EU adoption of the scheme
- Current size: As a mandatory procurement standard for US Government this has very strong market influence
- Aims: Voluntary label to certify products meeting minimum energy efficiency criteria.
- Administrative body: EPA ENERGY STAR
- Website: http://www.energystar.gov/certified-products/certified-products?c=products.pr_find_es_products

As previously discussed, it was recommended that UPS is adopted, while servers and storage should be assessed during their next revision of ENERGY STAR. In particular, server criteria are likely to be set based on power-performance benchmarking.

6.3 Data audits and ratings

There are many different certification schemes which cover energy efficiency in data centres. Certification generally works on a points scheme, with various actions and activities accumulating points to give a total score. Each scheme has its own points and value system with a surprising range and variety of approaches, but all of which are relatively complex. Research to compare and evaluate the relative merits of the schemes is not available and it is therefore not possible to recommend one based purely on technical details.

6.3.1 Blue Angel for Data Centres

- Geography: Primarily Germany
- Current size: unknown
- Aims: Consumer facing eco label award for efficient data centre operation.
- Administrative body: RAL GmbH
- Website: http://www.blauer-engel.de/en/products_brands/vergabegrundlage.php?id=226b

This covers the operation and ongoing management of the data centre with quantitative targets for efficiency as well as equipment efficiency targets. Because it is relatively new and only recently translated into English, uptake is expected to be very limited. While there are some interesting approaches, it is not yet clear how practical it is to audit and apply.

Harmonisation is not recommended at this stage. However, an assessment in the future may help guide future policy.

6.3.2 BREEAM for Data Centres

- Geography: Originally and primarily UK but with global operation including under license in a few other European countries
- Current size: There are a limited number of data centres with BREEAM awards
- Aims: Five level awards scheme for new data centre designs based on energy efficiency and other eco-criteria.
- Administrative body: BRE Global
- Website: http://www.breeam.org/page.jsp?id=157

BREEAM's heritage is from other, people oriented, buildings and this can be seen by the wide range of criteria such as use of reclaimed materials, transport links and health and wellbeing. As a result, harmonisation of the complete set of criteria is not recommended. In addition, LEED, as an American certification scheme has wider recognition within the data centre industry.

6.3.3 LEED for Data Centres

- Geography: US
- Current size: applied internationally but use limited to large data centres
- Aims: Four level rating system for new data centres and data centre operation
- Administrative body: USGBC
- Website: http://www.usgbc.org/credits/data-centers---new-construction/v4

LEED is very similar to the BREEAM scheme. While in theory it does not have the global coverage of BREEAM, it is better recognised. Similarly, it uses a relatively conservative set of qualitative criteria to assess efficiency based primarily on PUE.

6.3.4 ENERGY STAR for Data Centres Buildings

- Geography: USA
- Current size: 51 certified data centres in US
- Aims: Recognition of top quartile of data centres by PUE.
- Administrative body: EPA ENERGY STAR
- Website: http://www.energystar.gov/?c=prod_development.server_efficiency

ENERGY STAR takes the data centres who submit for assessment and awards certification based on the top quartile of PUE from the previous year. This is a pragmatic approach but since it is based on previous year's information, it does not offer a way to harmonise, nor does it cover the IT.

6.3.5 Singapore Standard SS 564

- Geography: Singapore
- Current size: 10 data centres
- Aims: Certification of data centre modelled on energy management systems
- Administrative body:
- Website: http://www.ida.gov.sg/Collaboration-and-Initiatives/Initiatives/Store/Green-Data-Centre-Standard

This standard is costly to implement since it requires large quantities of data and measurements including supply and return air temperatures. It is also largely an energy management system which means it is not possible to make comparisons between data centres. It was originally intended that this system would be introduced to other regions in the Asia Pacific but it is not clear what progress has been made. While there is a lot of value in the availability of energy management certification it is not clear that market demand will drive it forward.

6.3.6 Singapore Green Mark for Data Centres

- Geography: Singapore
- Current size: unknown
- Aims: Certification for efficient data centres
- Administrative body: Singapore Building and Construction Authority
- Website: http://www.bca.gov.sg/greenmark/green_mark_buildings.html

6.3.7 EU Code of Conduct for Data Centres

Certification requires the submission of one month's worth of data and an action plan to implement the best practices. It has a comparatively high number of participating data centres (almost 200), but the barrier to entry is very low since it is free and there is no independent auditing or assurance.

6.3.8 CEEDA

- Geography: UK but plans to launch globally
- Current size: This is a new scheme and has only recently left pilot stage
- Aims: Advisory auditing of data centre operations based on the EU Code of Conduct Best Practice and 3 level certification
- Administrative body: British Computer Society
- Website: http://ceeda.bcs.org/

CEEDA is an independent audit of a data centre, based on the actual level of implementation of the EU Code of Conduct Best Practices. This is a very in-depth audit, providing advisory as well as certification and requires a skilled auditor. Due to the level of detail in the Best Practices, it provides the best assessment of efficiency but at a higher cost. Anecdotally, at least one data centre in Australia has been audited by the CEEDA scheme, and found it was valuable.

As an advisory service, it could be integrated as an option alongside NABERS rating, and could also provide a route to applying for financing based on the results of the audit. However, the depth of the audit means this is better suited to larger data centres and an alternative is required for small and medium data centres.

6.4 Metrics and Reporting

Metrics and reporting standards for data centres is still a new area, and development has progressed slowly, with the exception of PUE. There are currently no widely used metrics for comparing data centre efficiency, and some experts in the industry think that these are not possible, or useful.

6.4.1 ISO/IEC JTC 1/SC 39

- Geography: Global
- Current size: Under development
- Aims: Standardise data centre efficiency metrics, include PUE and Data center Performance Per Energy (DPPE)
- Administrative body: ISO

- Website: http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=654019

This is refining the PUE and will set standard measurement guidelines. Aligning NABERS with this standard or influencing the standards development with experience from NABERS is unlikely to create any problems or risk.

A complete data centre metric is also being developed called DPPE but progress has been difficult. There are some concerns that the metric could be accurate and sensible in theory but not useful in practice since it requires a lot of measurements and proxies. However, as an ISO standard it is likely to be used by some data centres, particularly in Korea and Japan.

6.4.2 Fixed to variable energy ratio – FVER

- Geography: Global
- Current size: unknown (proposed by Liam Newcombe , British Computer Society)
- Aims: Metric for comparing variation in IT (or data centre) energy consumption in relation to the work being done.
- Administrative body: n/a
- Website: http://dcsg.bcs.org/data-centre-fixed-variable-energy-ratio-metric-dc-fver

Ideally, if no productive work is done then the data centre and IT equipment should consume no energy. The energy consumption in a data centre would therefore vary widely depending on the workload, and would for example drop dramatically at night when no one is working. This metric is designed to show the magnitude of the variation based on the energy consumption and self-determined productivity indicators. The main advantage of FVER is that it can be applied relatively easily and relates directly to the specific operations of the business. As such it is well suited as an internal metric for identifying inefficiency and tracking improvement.

However, the metric does not directly measure efficiency per unit of work, but uses the variability as a proxy for efficiency. It is therefore possible in theory for a data centre using half the energy but with the same proportional variation in energy to produce identical efficiency ratings. However, this is unlikely in practice. There is no widely available test data for this metric but a metric which targets and encourages reduction in energy consumption when no work is done is likely to drive large savings. The metric is therefore currently not suited for comparing between data centres since it requires the user to decide what proxy for productivity is being used.

6.4.3 SPECpower SERT

- Geography: Global
- Current size: 100+ members and associates include universities and major IT equipment manufacturers
- Aims: Metric and testing suite for server performance and power consumption
- Administrative body: SPEC
- Website: http://www.spec.org/power/

This has been discussed in Section **Error! Reference source not found.** and will be used in ENERGY TAR. It is the most useful server metric and should be used as the basis of other server policy measures. However, as a privately owned metric, the ability to influence the metric in future revisions is more limited.

6.4.4 WRI GHG Protocol ICT Sector Guidance

- Geography: Global
- Current size: unknown
- Aims: Additional guidance for GHG emissions reporting
- Administrative body: WRI
- Website: http://www.ghgprotocol.org/feature/ghg-protocol-product-life-cycle-accounting-and-reporting-standard-ict-sector-guidance

The GHG protocol is designed for reporting of GHG gases but is not suited for comparison. As a result, it has very limited use in policy.

6.4.5 ETSI TS 103 199 and ITU L.1410

- Geography: Global
- Current size: unknown
- Aims: Life cycle assessment guidelines for data centres and data centre services
- Administrative body: ETSI and ITU
- Website: http://webapp.etsi.org/ewp/copy_file.asp?wki_id=9eHgCXpzGrhjqjqllvTUI
  http://www.itu.int/rec/T-REC-L.1410

These are both very similar metrics based on ISO 14040 for life cycle analysis. This is not yet relevant to the Australian policy landscape

6.4.6 Open Data Center Alliance

- Geography: Global
- Current size: 300+ members
- Aims: Create open, interoperable standards for cloud computing, including cloud services metrics
- Administrative body:
- Website: http://www.opendatacenteralliance.org/

This has been discussed in Section 5.4.4.5 and appears to be the most likely body to develop metrics to allow comparison between cloud services. This metric is likely to drive efficiencies throughout the data centre, particularly for larger cloud providers, as well as providing a way to demonstrate savings when applying for financing.

6.5 Data centre operational guidance and training

These schemes provide in depth information about how to assess and efficiently operate a data centre. As such they are generally designed for internal use by the data centre operators, rather than public certification.

6.5.1 ASHRAE TC 9.9

- Geography: North America
- Current size: This is a de facto global standard
- Aims: Originally setting thermal and humidity guidelines for operating data centres to ensure that IT equipment operates safely and reliably. It is now expanding to cover all areas of data centre operation
- Administrative body: ASHRAE
- Website: http://tc99.ashraetcs.org/

ASHRAE standards were developed with IT equipment manufacturers to set safe environmental operating ranges. The 2008 and 2011 guidelines significantly extended the thermal and humidity operating windows and thus allowed greater energy efficiencies to be achieved in the infrastructure with the assurance that new and existing IT equipment would still operate reliably. Although it is primarily an American standard, it is used globally due to the support of IT equipment manufacturers. Advice to small and medium data centres should refer to and recommend harmonising with these guidelines.

6.5.2 The Green Grid Data Centre Maturity Model (DCMM)

- Geography: Global
- Current size: n/a
- Aims: Provides roadmap for assessing efficiency and planning efficiency improvements.
- Administrative body: The Green Grid
- Website: http://www.thegreengrid.org/en/Global/Content/white-papers/DataCenterMaturityModel

The DCMM sets forth various levels of operating practices and efficiencies across the different parts of the data centre, and assigns different levels of maturity. The aim of this is to allow a data centre to monitor its progress and ensure a balanced approach to efficiency improvements. There are some high profile adopters of this, including all central UK Government IT services.

The model is currently undergoing a review and revision by The Green Grid with development undertaken by contributing members. It remains a useful internal and advisory tool but harmonisation and participation are unlikely to be of high value for impacting the wider Australian and New Zealand market.

6.5.3 Open Compute Project (OCP)

- Geography: Global
- Current size: n/a
- Aims: Provide open source IT equipment, data centre designs and standards to improve interoperability and efficiency
- Administrative body: Open Compute Project Foundation
- Website: http://www.opencompute.org/

The OCP publishes highly technical open source designs for servers, racks and data centres and can be considered the best currently available technology. Because it is so technical, it is unlikely that it can be usefully used within policy development. However, it provides a best practice ceiling when assessing technology and policy ambition.

6.5.4 EU Code of Conduct for Data Centres

- Geography: EU with a number of international data centres
- Current size: 190 participating data centres and 200 endorsing suppliers
- Aims: Provide technical best practice guidelines, and recognise data centres and suppliers using best practice
- Administrative body: EC JRC
- Website: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

The Code of Conduct was one of the earliest programs and maintains a large, ambitious remit. As such, it lacks the focus of other programs. It has developed data centre guidance, a certification scheme for data centres and data centre suppliers, as well as a large database of energy efficiency performance information.

The Code of Conduct Best Practice guidance is adopted and used as a reference in a large number of other schemes, and continues to be updated. The guidance also benefits from an open development process which is independent of equipment suppliers.

The Best Practice guide is a valuable document to form the basis of advisory tool and audits.

6.6 Harmonisation Recommendations

The very early stage of many of these schemes and of data centre policies in general means that harmonisation is still difficult to recommend. This is because it is difficult to assess which schemes will be more effective. A variety of approaches across different markets may still be the most sensible option since it allows a number of options to be tested and evaluated in the market.

For product standards, ENERGY STAR is effective and harmonisation is the simplest route to introduce a label quickly. However, as discussed previously, the policy landscape and process means that efficiency levels could be made more ambitious. Therefore any harmonised HEPS needs support with additional policies such as MEPS for UPS and a rating label for IT equipment.

No harmonisation is recommended for data centre ratings and audits since they have not demonstrated they are any more effective than NABERS. In addition, they tend to be complex and expensive. This will limit the uptake which means that it does not drive competition within the market.

The metrics which form the basis of the standard labels and ratings are a useful point of harmonisation. SPEC SERT, SNIA Emerald, PUE have all been developed and are well established. The Open Data Centre Alliance is also developing a metric for cloud services and there is scope to collaborate on the metrics and adopt it in future.

Harmonisation of operational guidance and training is difficult to recommend since there are no policies linked to training. However, future policies could be associated with the EU Code of Conduct for Data Centres which has an open development process and is widely used and respected.

7. A recommended course of action…

7.1 Introduction

Based on the modified The Green Grid data centre definition, and using a 10 kW minimum size limit there are over 48 000 data centres in Australia and New Zealand. Over 95% of these are under 150 kW, with enterprise and large data centres over 750 kW accounting for just 0.35% of the total number of data centres. When calculated by total energy, the small data centres represent 51% of consumption in 2013, medium data centres 17%, enterprise data centres 26% and mega datacentres represent 6%.

The policies and programs discussed in the preceding sections show there are distinct differences between small and large data centres. As a result, the approach and consultation should be targeted separately at these market sectors. While the E3 is responsible for introducing efficiency standards and information measures, other industry and government agencies would need to be consulted where other measures are proposed.

Table 16 Summary of policy energy savings

Policy name	Policy type	Cumulative energy saving 2015-2030
NABERS data centre infrastructure	Voluntary rating label	3.5 TWh (12.6 PJ)
NABERS IT equipment, whole data centre	Metrics	Unknown
Data centre service metric	Metric	Included as part of the data centre service label
Data centre service label	Voluntary rating label	2.9 TWh (10.4 PJ)
Building Codes for new and refurbished data centres	minimum efficiency standards, metering	3.4 TWh (1.2 PJ)
Energy Efficiency Disclosure	information disclosure (Colocation)	Included as part of the data centre infrastructure policies
SPEC SERT	Metric (Server)	Included as part of the comparative energy rating label
SNIA Emerald Program	Metric (Storage)	Included as part of the comparative energy rating label
ENERGY STAR	HEPS	Included as part of the comparative energy rating label figure
Comparative energy rating label	Mandatory energy rating label	1.7 TWh (6.1 PJ) server 0.4 TWh (1.4 PJ) storage
Minimum Energy Performance	MEPS (UPS)	0.26 TWh (0.94 PJ)

Policy name	Policy type	Cumulative energy saving 2015-2030
Cloud migration	Information	1.2 TWh (4.3 PJ)
Government Procurement	Procurement	Included as part of the savings reported elsewhere
Financial mechanisms	Financial mechanisms	Included as part of the savings reported elsewhere
Research	Research	None quantified
Training	Training	None quantified

7.2 Prioritisation – savings potential

In terms of savings potential, the data centre infrastructure policies have the most impact (Building Codes, NABERS Data Centre infrastructure label, government procurement standards and minimum standards for new and refurbished data centres). Savings due to the NABERS rating is dependent on high uptake and policies are needed to support and ensure this happens. The first recommendation is a Government Procurement requirement for data centres. It is estimated that this results in 10 per cent of Enterprise and Mega size data centres impacted. Over time, procurement requirements are then increased and a mandatory requirement to use the certificate for all colocation data centres is recommended. Due to the longer lifetimes of the data centre, savings take longer to be realised.

A small increase in cloud migration driven by awareness raising and the implementation of a voluntary data centre services label has the next largest impact. This is because the savings are very high for each data centre migrated - approximately 80%. This makes it extremely sensitive to uptake, and a more successful policy has the potential to save more than all the other policies combined. Because a migration is not dependent on the lifetimes of the data centre or server, savings are made very soon after the policy is implemented.

HEPS and rating labels for IT servers are the third major opportunity to make savings. While the efficiency gains per server are small, it has an impact over the whole market. Because servers are all very similar, simply creating a label drives all the manufacturers to improve their products, without the need for additional policies.

Efficiency standards for servers and UPS create the smallest savings. This is because of the limited lifespan of the UPS policy and the small fraction of total energy consumption of the storage equipment.

7.3 Prioritisation – date of policy introduction

Policies that can be directly implemented by the commissioning program, E3, are most likely to be established. This means that ratings labels for servers, storage, UPS and data centre metrics are the highest priority. UPS are the easiest to develop since there are already examples to base the development on. Secondly, there is a developed metric and soon to be a large amount of accurate data for IT servers. This reduces the resources needed to develop criteria and have a level of confidence in its accuracy. However, this will require regular updates to ensure it remains relevant. There is still limited data and experience to draw from to develop criteria for storage and networking which could make them a significantly more complex and longer process. The most difficult area to develop a label is that for data centre services since it must start with the development of a metric.

Establishing Government procurement criteria, which should be based on NABERS, is expected to be relatively simple and other labels can then be regarded as secondary targets. Creating financial guidance based on existing literature is also expected to be relatively simple, but would need the cooperation of other departments and possibly state programs too, to encourage its use.

Mandatory measures require significant legislative work and evidence to prove that an intervention is justified. This means that information disclosure requirements and alterations to Building Codes are some of the most difficult to implement as they will involve longer and more formal processes.

It is not clear what scope there is to develop training and research priorities. In addition, these can require the commitment of large amounts of funding.

7.4 Prioritisation timeline

Table 17 provides a timeline for the introduction into the market of recommended policies based on an assessment of the maturity of the policies and the savings. There are higher and lower priorities.

Higher Priorities

- Policies linked to improving infrastructure efficiency and encouraging uptake of NABERS are the first priority recommendation (introduced around 2015). As NABERS and PUE are well established, the projected savings are high, and it takes a long time from implementation to the savings being realised. Within these policies, the first and quickest to establish is Government procurement;
- NABERSNZ has recently begun in New Zealand for commercial buildings. Some technical changes may be needed to implement NABERSNZ for data centres in the future. As New Zealand has a high proportion of renewable energy, the rating could be based on energy use rather than greenhouse gas emissions if required;
- Secondly (introduced from 2016) are server efficiency measures. Reliable data and metrics are available and the savings are high. In addition, these can be actioned by the E3 Program and have immediate savings from the implementation date;
- Thirdly (introduced from 2016 to 2017) are cloud migration measures as the potential savings are very high. Developing metrics for cloud and data centre services is an essential prerequisite for introducing a label and is therefore a high priority. While this is likely to take a long time and relatively large amount of resources, industry efforts are already underway, and it is within the remit of the E3 Program;
- Fourthly, (introduced from 2017) providing guidance, information and support through a centralised site and procurement advice to assists SMEs and provide assurance to the market which could address some of the barriers to energy efficiency and it requires limited intervention;
- Fifth (introduced from 2018) introduction of an internationally harmonised voluntary label based on the data centre services metrics developed. This helps drive a relatively small amount of migration to cloud services but has a large saving. In addition it is within the remit of E3; and
- The final high priority is the introduction in 2019- 2020 are measures that require the disclosure of NABERS for data centre infrastructure for colocation data centres and the introduction of additional Building Code requirements for metering and minimum efficiency standards in new and refurbished data centres. The very large projected savings warrant mandatory intervention, but are not introduced earlier since more time is needed for due process.

Lower Priorities

- For UPS, MEPS combined with HEPS labelling policies is similar to that described earlier for servers but the savings are very small and therefore are a lower priority;
- Input into the Australia Cloud Computing Strategy (Department of Finance and Deregulation) to raise awareness may highlight the energy savings potential but is a lower priority; and
- A storage label is likely to be more limited than servers because there are fewer of them in the data centre. It is also recommended that it is introduced later than for servers because of the limited data available and additional resources which may be needed to develop criteria. Despite it being within the E3 Programs remit, its priority is low.

The policy timeline presented in Table 17 summarises the discussion.

Table 17 Timeline and prioritisation for policy implementation

Timeline	Higher priority	Lower priority
2015	NABERSNZ to adopt data centres metric Government data centres procurement two tiers set at NABERS data centre infrastructure 3 star minimum, 4 star recommended	-
2016	IT servers HEPS/rating label, Introduction of a metric for data centre services	ENERGY STAR UPS, Cloud energy awareness raising
2017	Data centre energy efficiency website portal, Finance guidance, Data Centre Information Management guidance	IT storage HEPS/rating label, UPS MEPS, Research training opportunities
2018	Data centre services rating	Research strategy
2019	Mandatory disclosure of NABERS DC rating for colocation facilities	-
2020	Building Codes introduce energy metering and energy efficiency requirements for new and refurbished data centres. Government data centres procurement rises to NABERS data centre infrastructure 4 star minimum, 5 star recommended, IT Server HEPS/rating label updated	-
2021	-	IT storage HEPS/rating label updated
2022/2023	-	-
2024	IT Server HEPS/rating label updated	-
2025	-	IT storage HEPS/rating label updated

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Appendix A – Existing Data Centre Definitions

EU Code of Conduct for Data Centres

http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

For the purposes of the Code of Conduct, the term “data centres” includes all buildings, facilities and rooms which contain enterprise servers, server communication equipment, cooling equipment and power equipment, and provide some form of data service (e.g. large scale mission critical facilities all the way down to small server rooms located in office buildings).

The focus of this Code of Conduct covers two main areas:

1. 1. IT Load – this relates to the consumption efficiency of the IT equipment in the data centre and can be described as the IT work capacity available for a given IT power consumption. It is also important to consider the utilisation of that capacity as part of efficiency in the data centre
2. 2. Facilities Load – this relates to the mechanical and electrical systems that support the IT electrical load such as cooling systems (chiller plant, fans, pumps), air conditioning units, UPS, PDU’s etc.

BREEAM

http://www.dgbc.nl/images/uploads/20120229_BRL2012-v1-0_BREEAM-NL_Datacenters-EN.pdf

Project types that can be assessed using BREEAM-NL

Assessment with BREEAM-NL can be conducted for the following types of building projects:

- New construction
- Large scale refurbishment of existing buildings
- New built extensions to existing buildings

Existing buildings that do not undergo a large-scale refurbishment are excluded from the scheme. BREEAM in USE is available for this category.

Large-scale refurbishment of existing buildings

Large-scale refurbishment in which the building envelope (facade, floor, roof, windows, doors) and the building services (lighting, HVAC) are addressed with the goal to extend the service life of a building.

In data centres, the data centre facilities need to be refurbished as well i.e. the data hall and the cooling plant for the data hall.

Small-scale refurbishment

BREEAM-NL is not meant to assess small-scale renovation of existing buildings where the thermal skin or the building services are not addressed. It does not address those that do not lead to change in building function.

New built extensions to existing buildings

Assessments of a new built extension to an existing building, possibly in combination with a refurbishment of the existing building. If the new extension is assessed separately and if the extension uses the building services or facilities of the existing building, these should be included in the assessment. Further guidance is given for these cases in the compliance notes.

Building types that can be assessed using BREEAM-NL

BREEAM Data Centres can be used to assess buildings that consist predominantly of data halls with associated function areas (where present). This means the data hall is the main function of the building or the data hall is separable in a mixed-use development and can be assessed separately.

Data halls

Typically any space containing banks of data storage equipment (i.e. servers), plus any associated support spaces (e.g. circulation space and technical areas like switch rooms, UPS rooms, battery rooms, climate control rooms, rooms for generators and storage tanks). The primary function of the building must be the physical or virtual storage, management, and dissemination of data and information. The data halls and any related plant space should make up a significant majority (>75%) of the floor area of the building. Where this is not the case, advice can be sought from DGBC on the use of this scheme.

The following building functions/spaces can be included in the BREEAM Data Centres assessment where provided for the purposes of operating the data centre or for the use of staff running the facility:

- Reception and waiting areas
- Office areas (including meeting and training rooms)
- Workshops (e.g. assembly areas)
- Staff restaurant and/or kitchen facilities
- Staff gym
- Storage and waste management areas
- Restrooms, WCs and changing facilities
- Ancillary areas e.g. technical areas, circulation space, climate control rooms serving the other associated function areas

The above list is not exhaustive, but serves to indicate the type of areas covered by the scope of this BREEAM scheme. Where a proposed building contains a small additional function/area that is not listed above, the building can still be assessed using this scheme. If the assessor has reason to believe that this scheme is not appropriate given the small additional function/area type, BRE Global should be contacted for advice.

Unless otherwise stated, BREEAM Data Centres cannot be used to assess any of the above functions/spaces as standalone developments, i.e. the Data Centres scheme cannot be used to assess and certify an office or gym that does not form a part of a data centre building. Such buildings can be assessed using one of the other standard BREEAM schemes or, where appropriate, the BREEAM Bespoke scheme.

Function areas and the Building Decree

The floor plans of computer areas and data centres contain many specific room names. Plans for a computer room or data centre in the Netherlands need to be compliant with the Building Decree. To comply with best practice, the plans and technical documents should use the same names and function areas as stated in the

Building Decree.

The following is a classification of the data centre function areas in accordance with the Building Decree:

1. Technical area - light industrial function;
2. Common area - office function, gathering function;
3. Common traffic areas - transport and access functions.

The entire floor area of a computer room or data centre has to be designated to one or more of the above categories of function areas. This includes corridors, elevators, stairways, shafts, etc. must be designated to a function area.

The various functions can best be shown in a shaded view drawing.

Data hall

- Computer room with computer floor and racks - technical area - light industrial function
- Support spaces (switch rooms, UPS rooms) - technical area - light industrial function

Associated function areas

- Office accommodation - occupied space - office function
- Meeting rooms - occupied space - lounge / meeting function
- Workshops - occupied space - light industrial function
- Restaurant / canteen facilities - occupied space – lounge / meeting function
- Storage facilities - occupied space - light industrial function
- Traffic circulation space – common traffic areas – traffic function

Determining the type of BREEAM-NL assessment Data Centre

The approach to the assessment of associated function areas within a Data Centre building differs depending on the size of associated function areas provided. The BREEAM-NL Assessment tool selects the appropriate BREEAM-NL issues for assessment based on the scope of the building requiring assessment, as defined by the BREEAM-NL assessor.

Data centres with no associated function areas

Where a data centre has no associated function areas the BREEAM-NL Data Centres scheme can still be used. In such cases, the BREEAM-NL issues not applicable for the assessment of these types of data centre are filtered out by the BREEAM-NL Assessment tool.

Determining the type of BREEAM Data Centres assessment – issue filtering

As above the approach to the assessment of associated function areas within the building differs depending on the size of associated function areas provided. Depending on the assessment type non applicable issues/categories are filtered out of the BREEAM Assessor's tool. Technical Checklist A7: Determining the type of BREEAM Data Centres assessment – issue filtering outlines the applicability of issues relating to assessment type. If the associated function areas are exceeding 1,500 m2 please contact DGBC. Possibly the associated function areas needs to be assessed with a different BREEAM-NL scheme (eg, New Build) and the data hall has to be assessed separately with BREEAM-NL Datacenters.

Mixed use developments

Data centres within a mixed use development/building can be assessed using BREEAM Data Centres, provided the data centre area is separable from the other mixed use elements of the building.

Small data halls within office developments

BREEAM-NL New Build may be a more appropriate scheme to use for buildings that are predominantly office space, but contain a small proportion of data storage space. If BREEAM-NL New Build is deemed to be an inappropriate scheme to assess such a building please contact BRE Global.

Buildings that do not fit the scope of the BREEAM Data Centres scheme

Building types not covered by the scope of BREEAM Data Centres and/or any of the other standard

BREEAM schemes (including BREEAM-NL New Build) can be assessed using the BREEAM-NL Bespoke

scheme.

Singapore SS564

http://www.ida.gov.sg/Collaboration-and-Initiatives/Initiatives/Store/Green-Data-Centre-Standard

A purpose built/dedicated facility used to house computer systems and associated components, such as telecommunications and storage systems

ASHRAE

Computer Room: A room whose primary function is to house equipment for the processing and storage of electronic data that has a design electronic data equipment power density exceeding 20 watts/ft2 of conditioned floor area (215 watts/m2) and is not a data center.

Data Center: A room or building, or portions thereof with a primary function to house electronic equipment for the processing and storage of electronic data that has a design electronic data equipment power density exceeding 20 watts/ft2 of conditioned floor area (215 watts/m2) and either:

1. has a design in compliance with ANSI/TIA942 Tier II or greater or,
2. is designed with redundant mechanical cooling capacity units on the entire mechanical system serving the electronic equipment, such that any single piece of mechanical cooling equipment can be removed from service without affecting design capacity, and the entire mechanical cooling system serving the electronic equipment is supported by a redundant power system (i.e. backup generators, etc) aside from the Uninterruptible Power Supply (UPS).

Blue Angel

http://www.blauer-engel.de/en/products_brands/search_products/produkttyp.php?id=598

Within the scope of these Basic Criteria a data center is defined as follows:

A data center is capable of securely, permanently and centrally processing large amounts of data over a long period of time. In doing so, the data center shall still possess these qualities even if individual qualities are not being used, for example, the operation over a long period of time.

The qualities required can be put in more concrete terms as follows:

1. Data processing includes, for example, the collection, transfer, computation or storage of data.
2. A secure way of data processing is described in terms of supply engineering by the "minimum security" for a "controlled shutdown of the computers without data loss in the case of damage to the supply units".
3. Large amounts of processed data are relatively related to the technological capabilities of the state of the art and, thus, represent a dynamic factor over time.
4. The operation to be provided continuously over a long period of time at a data center requires measures to control influences going beyond a period of critical impact, such as heat, humidity or dust.

Operators of data centers and/or providers of data center services are eligible to apply for award of the Blue Angel eco-label. The Blue Angel eco-label is awarded to the entire data center building defined by a specific location and company name. If one company runs several data centers located at different locations and/or independent data centers, each one shall be considered as an independent data center for which a separate application for the Blue Angel eco-label needs to be filled.

ETSI[38] (same as EU Code of Conduct)

Data centre: includes all buildings, facilities, offices and rooms which contain enterprise servers, server communication equipment, cooling equipment and power equipment, and provide some form of data service (see note)

NOTE: E.g. large scale mission critical facilities all the way down to small server rooms located in office buildings.

NABERS

http://www.nabers.gov.au/public/WebPages/Home.aspx

A data centre is a facility that is dedicated to the housing and operation of IT equipment. It may be a standalone facility or a facility within a building that also includes other facilities such as offices.

For the purposes of this rating, the data centre includes all services and equipment directly located in or servicing the IT equipment area (typically defined by a closed off area with dedicated space temperature control) and does not include facilities serving other areas such as supporting office space.

TIA 942

http://global.ihs.com/doc_detail.cfm?currency_code=USD&customer_id=21254F2B5B0A&oshid=21254F2B5B0A&shopping_cart_id=21254F2B550A&rid=TIA&input_doc_number=TIA-942&country_code=US&lang_code=ENGL&item_s_key=00414811&item_key_date=860905&input_doc_number=TIA-942&input_doc_title=

Data centre:

A building or portion of a building whose primary function is to house a computer room and its support areas

Computer room

: An architectural space whose primary function is to accommodate data processing equipment

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[38] The European Telecommunications Standards Institute (ETSI) is an independent, non-profit, standardization organization in the telecommunications industry (equipment makers and network operators) in Europe

ENERGY STAR Data centres

http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

ELIGIBILITY CRITERIA

Applies to spaces specifically designed and equipped to meet the needs of high density computing equipment such as server racks used for data storage and processing.

Typically these facilities require dedicated uninterruptible power supplies (UPS) and cooling systems.

✷ It should not be used to represent a server closet or computer training area.

Green Grid Life Cycle Assessment

http://www.thegreengrid.org/~/media/WhitePapers/WP45v2DataCentreLifeCycleAssessmentGuidelines.pdf

DATA CENTRE DEFINITION

A data centre is a structure, or group of structures, dedicated to the centralized accommodation, interconnection, and operation of information technology and network telecommunications equipment that provides data storage, processing, and transport services. A data centre encompasses all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability.

Australian Draft report

A data centre refers to a space that exclusively accommodates and manages IT devices, such as servers, storage units, and network devices, together with a space that accommodates devices for supporting these devices and their operations.

Physically a data centre may be either;

- an exclusive facility, which is built for exclusive use by the data centre and possesses only data centre functions within it,
- or a facility within a building used for non-data centre functions as well.

Appendix B – Data used for modelling

Number of Data centres – Baseline Scenario

Year	Small	Medium	Enterprise	Mega
2010	47500	950	150	11
2011	48000	950	150	13
2012	48500	950	150	15
2013	47000	950	150	15
2014	45800	950	157	16
2015	44500	950	164	17
2016	44000	959	171	18
2017	43500	968	178	19
2018	43000	977	185	20
2019	42500	986	192	20
2020	42000	995	199	21
2021	41500	1004	206	21
2022	41000	1013	213	22
2023	40500	1022	220	22
2024	40000	1031	227	23
2025	39500	1040	234	23
2026	39000	1049	241	24
2027	38500	1058	248	24
2028	38000	1067	255	25
2029	37500	1076	262	25
2030	37000	1085	269	25

Number of Data centres – Policy Scenario

Year	Small	Medium	Enterprise	Mega
2010	47500	950	150	11
2011	48000	950	150	13
2012	48500	950	150	15
2013	47000	950	150	15
2014	45800	950	157	16
2015	44500	950	164	17
2016	44000	959	171	18
2017	43300	968	179	19
2018	42600	977	188	20
2019	41900	986	195	21
2020	41200	995	202	22
2021	40500	1004	209	23
2022	39800	1013	216	24
2023	39100	1022	224	25
2024	38400	1031	232	26
2025	37700	1040	240	27
2026	37000	1049	248	28
2027	36300	1058	256	29
2028	35600	1067	264	30
2029	34900	1076	272	31
2030	34200	1085	280	32

Number of Data centres – Maximum Technical Savings Scenario

Year	Small	Medium	Enterprise	Mega
2010	47500	950	150	11
2011	48000	950	150	13
2012	48500	950	150	15
2013	47000	950	150	15
2014	45800	950	157	16
2015	42800	875	181	20
2016	39800	800	205	22
2017	36800	725	229	25
2018	33800	650	253	28
2019	30800	575	277	31
2020	27800	500	301	33
2021	24800	500	325	36
2022	21800	500	349	38
2023	18800	500	373	40
2024	15800	500	397	40
2025	12800	500	421	40
2026	12800	500	445	40
2027	12800	500	445	40
2028	12800	500	445	40
2029	12800	500	445	40
2030	12800	500	445	40

New data centre PUE – Baseline Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.30	2.30	2.00	1.80
2011	2.20	2.20	1.90	1.75
2012	2.00	2.00	1.80	1.65
2013	2.00	1.90	1.75	1.50
2014	2.00	1.90	1.75	1.45
2015	2.00	1.80	1.69	1.40
2016	2.00	1.80	1.69	1.40
2017	2.00	1.80	1.64	1.40
2018	2.00	1.80	1.64	1.40
2019	2.00	1.80	1.60	1.40
2020	2.00	1.80	1.60	1.40
2021	2.00	1.80	1.60	1.40
2022	2.00	1.80	1.60	1.40
2023	2.00	1.80	1.60	1.40
2024	2.00	1.80	1.60	1.40
2025	2.00	1.80	1.60	1.40
2026	2.00	1.80	1.60	1.40
2027	2.00	1.80	1.60	1.40
2028	2.00	1.80	1.60	1.40
2029	2.00	1.80	1.60	1.40
2030	2.00	1.80	1.60	1.40

New data centre PUE – Policy Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.30	2.30	2.00	1.80
2011	2.20	2.20	1.90	1.75
2012	2.00	2.00	1.80	1.65
2013	2.00	1.90	1.75	1.50
2014	2.00	1.90	1.75	1.45
2015	2.00	1.80	1.67	1.40
2016	1.99	1.79	1.67	1.40
2017	1.99	1.79	1.63	1.40
2018	1.99	1.79	1.63	1.40
2019	1.99	1.79	1.59	1.40
2020	1.80	1.55	1.38	1.30
2021	1.80	1.55	1.38	1.30
2022	1.80	1.55	1.38	1.30
2023	1.80	1.55	1.38	1.30
2024	1.80	1.55	1.38	1.30
2025	1.80	1.55	1.38	1.30
2026	1.80	1.55	1.38	1.30
2027	1.80	1.55	1.38	1.30
2028	1.80	1.55	1.38	1.30
2029	1.80	1.55	1.38	1.30
2030	1.80	1.55	1.38	1.30

New data centre PUE – Maximum Technical Savings Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.30	2.30	2.00	1.80
2011	2.20	2.20	1.90	1.75
2012	2.00	2.00	1.80	1.65
2013	2.00	1.90	1.75	1.50
2014	1.60	1.50	1.40	1.20
2015	1.60	1.50	1.40	1.20
2016	1.60	1.50	1.40	1.20
2017	1.50	1.40	1.20	1.10
2018	1.50	1.40	1.20	1.10
2019	1.50	1.40	1.20	1.10
2020	1.50	1.40	1.20	1.10
2021	1.50	1.40	1.20	1.10
2022	1.50	1.40	1.20	1.10
2023	1.50	1.40	1.20	1.10
2024	1.50	1.40	1.20	1.10
2025	1.50	1.40	1.20	1.10
2026	1.50	1.40	1.20	1.10
2027	1.50	1.40	1.20	1.10
2028	1.50	1.40	1.20	1.10
2029	1.50	1.40	1.20	1.10
2030	1.50	1.40	1.20	1.10

Retrofit data centre PUE – Baseline Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.50	2.50	2.10	1.90
2011	2.50	2.50	2.00	1.90
2012	2.40	2.50	1.95	1.90
2013	2.40	2.00	1.90	1.80
2014	2.30	2.00	1.90	1.80
2015	2.20	2.00	1.90	1.80
2016	2.10	2.00	1.90	1.70
2017	2.10	2.00	1.90	1.70
2018	2.10	2.00	1.90	1.70
2019	2.10	2.00	1.90	1.70
2020	2.10	2.00	1.80	1.70
2021	2.10	2.00	1.85	1.70
2022	2.10	2.00	1.70	1.70
2023	2.10	2.00	1.70	1.70
2024	2.10	2.00	1.70	1.70
2025	2.10	2.00	1.70	1.50
2026	2.10	2.00	1.70	1.50
2027	2.10	2.00	1.70	1.50
2028	2.10	2.00	1.70	1.50
2029	2.10	2.00	1.70	1.50
2030	2.10	2.00	1.70	1.50

Retrofit data centre PUE - Policy Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.50	2.50	2.10	1.90
2011	2.50	2.50	2.00	1.90
2012	2.40	2.50	1.95	1.90
2013	2.40	2.00	1.90	1.80
2014	2.30	2.00	1.90	1.80
2015	2.20	2.00	1.89	1.80
2016	2.09	1.99	1.89	1.70
2017	2.09	1.99	1.89	1.80
2018	2.09	1.99	1.89	1.80
2019	2.09	1.99	1.89	1.80
2020	1.90	1.80	1.61	1.55
2021	1.90	1.80	1.63	1.55
2022	1.90	1.80	1.59	1.55
2023	1.90	1.80	1.59	1.55
2024	1.90	1.80	1.59	1.55
2025	1.90	1.80	1.59	1.55
2026	1.90	1.80	1.59	1.55
2027	1.90	1.80	1.59	1.55
2028	1.90	1.80	1.59	1.55
2029	1.90	1.80	1.59	1.55
2030	1.90	1.80	1.59	1.55

Retrofit data centre PUE – Maximum Technical Savings Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.50	2.50	2.10	1.90
2011	2.50	2.50	2.00	1.90
2012	2.40	2.50	1.95	1.90
2013	2.40	2.00	1.90	1.80
2014	1.70	1.60	1.50	1.30
2015	1.70	1.60	1.50	1.30
2016	1.70	1.60	1.50	1.30
2017	1.70	1.60	1.50	1.30
2018	1.70	1.60	1.50	1.30
2019	1.70	1.60	1.50	1.30
2020	1.70	1.60	1.50	1.30
2021	1.70	1.60	1.50	1.30
2022	1.70	1.60	1.50	1.30
2023	1.70	1.60	1.50	1.30
2024	1.70	1.60	1.50	1.30
2025	1.70	1.60	1.50	1.30
2026	1.70	1.60	1.50	1.30
2027	1.70	1.60	1.50	1.30
2028	1.70	1.60	1.50	1.30
2029	1.70	1.60	1.50	1.30
2030	1.70	1.60	1.50	1.30

Average data centre PUE - Baseline Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.71	2.64	2.46	2.20
2011	2.67	2.62	2.38	2.11
2012	2.62	2.60	2.30	2.03
2013	2.59	2.53	2.22	1.98
2014	2.55	2.46	2.13	1.90
2015	2.50	2.40	2.06	1.82
2016	2.44	2.33	2.00	1.74
2017	2.39	2.26	1.95	1.68
2018	2.34	2.20	1.91	1.63
2019	2.30	2.15	1.88	1.60
2020	2.26	2.10	1.85	1.57
2021	2.23	2.06	1.84	1.55
2022	2.20	2.03	1.80	1.54
2023	2.18	2.00	1.78	1.53
2024	2.16	1.99	1.75	1.52
2025	2.14	1.97	1.73	1.51
2026	2.13	1.97	1.71	1.49
2027	2.12	1.96	1.69	1.48
2028	2.11	1.96	1.68	1.46
2029	2.10	1.96	1.68	1.45
2030	2.10	1.96	1.68	1.44

Average data centre PUE - Policy Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.71	2.64	2.46	2.20
2011	2.67	2.62	2.38	2.11
2012	2.62	2.60	2.30	2.03
2013	2.59	2.53	2.22	1.98
2014	2.55	2.46	2.13	1.90
2015	2.50	2.40	2.05	1.82
2016	2.44	2.33	1.99	1.74
2017	2.38	2.26	1.94	1.69
2018	2.34	2.20	1.91	1.65
2019	2.30	2.14	1.88	1.61
2020	2.23	2.07	1.82	1.57
2021	2.17	2.01	1.77	1.53
2022	2.13	1.95	1.73	1.49
2023	2.08	1.90	1.68	1.46
2024	2.05	1.86	1.64	1.44
2025	2.02	1.83	1.60	1.42
2026	1.99	1.80	1.57	1.41
2027	1.97	1.79	1.55	1.40
2028	1.95	1.77	1.54	1.40
2029	1.93	1.76	1.54	1.40
2030	1.92	1.76	1.54	1.40

Average DC PUE - Maximum Technical Savings Scenario

Year	Small	Medium	Enterprise	Mega
2010	2.71	2.64	2.46	2.20
2011	2.67	2.62	2.38	2.11
2012	2.62	2.60	2.30	2.03
2013	2.59	2.53	2.22	1.98
2014	2.46	2.43	2.07	1.84
2015	2.40	2.39	1.90	1.65
2016	2.35	2.34	1.77	1.54
2017	2.29	2.29	1.67	1.43
2018	2.23	2.23	1.60	1.35
2019	2.18	2.17	1.54	1.29
2020	2.14	2.10	1.50	1.25
2021	2.10	1.96	1.47	1.22
2022	2.06	1.85	1.45	1.20
2023	2.03	1.75	1.44	1.19
2024	2.00	1.68	1.43	1.19
2025	1.99	1.63	1.43	1.18
2026	1.91	1.60	1.43	1.18
2027	1.85	1.58	1.43	1.18
2028	1.80	1.57	1.43	1.18
2029	1.77	1.56	1.43	1.18
2030	1.74	1.56	1.43	1.18

DC Power Load (W) - All Scenarios

Year	**Small**	**Medium**	**Enterprise**	**Mega**
2010	20	150	1000	3000
2011	20	150	1000	3000
2012	20	175	1500	3000
2013	20	200	1500	3000
2014	20	200	1500	3000
2015	20	200	1530	3050
2016	20	200	1560	3100
2017	20	200	1590	3150
2018	20	200	1620	3200
2019	20	200	1650	3250
2020	20	200	1680	3300
2021	20	200	1710	3350
2022	20	200	1740	3400
2023	20	200	1770	3450
2024	20	200	1800	3500
2025	20	200	1800	3500
2026	20	200	1800	3500
2027	20	200	1800	3500
2028	20	200	1800	3500
2029	20	200	1800	3500
2030	20	200	1800	3500

Percentage of data centre IT Load capacity used - All Scenarios

Year	**Small**	**Medium**	**Enterprise**	**Mega**
2010	20%	35%	51%	70%
2011	20%	35%	51%	70%
2012	20%	35%	52%	70%
2013	21%	35%	53%	70%
2014	22%	36%	54%	71%
2015	23%	37%	55%	72%
2016	24%	38%	56%	73%
2017	25%	39%	57%	74%
2018	26%	40%	58%	75%
2019	27%	41%	59%	76%
2020	28%	42%	60%	77%
2021	29%	43%	61%	78%
2022	30%	44%	62%	79%
2023	31%	45%	63%	80%
2024	32%	46%	64%	81%
2025	33%	47%	65%	82%
2026	34%	48%	66%	83%
2027	35%	49%	67%	84%
2028	36%	50%	68%	85%
2029	37%	51%	69%	86%
2030	38%	52%	70%	87%

Server power and utilisation – Baseline scenario

Year	New physical servers virtualised	New physical servers in cloud	Virtualisation ratio – standard virtualised	Virtualisation ratio - cloud	Approx. Utilisation	Server power (unvirtualised) (W)	Server power (virtualised)
2010	20%	14%	4.0:1	10:1	60%	237	467
2011	25%	16%	4.0:1	10:1	60%	223	481
2012	31%	18%	4.0:1	10:1	60%	220	441
2013	36%	21%	5.0:1	10:1	60%	183	512
2014	38%	22%	5.0:1	10:1	60%	185	519
2015	40%	23%	5.0:1	10:1	60%	184	516
2016	40%	24%	5.0:1	10:1	60%	185	518
2017	40%	25%	5.0:1	10:1	60%	165	461
2018	40%	25%	5.0:1	10:1	60%	166	466
2019	40%	25%	5.0:1	10:1	60%	170	475
2020	40%	25%	5.0:1	10:1	60%	175	490
2021	40%	25%	5.0:1	10:1	60%	160	448
2022	40%	25%	5.0:1	10:1	60%	166	466
2023	40%	25%	5.0:1	10:1	60%	170	475
2024	40%	25%	5.0:1	10:1	60%	175	490
2025	40%	25%	5.0:1	10:1	60%	160	448
2026	40%	25%	5.0:1	10:1	60%	166	466
2027	40%	25%	5.0:1	10:1	60%	170	475
2028	40%	25%	5.0:1	10:1	60%	175	490
2029	40%	25%	5.0:1	10:1	60%	160	448
2030	40%	25%	5.0:1	10:1	60%	160	448

Server power and utilisation – Policy scenario

Year	New physical servers virtualised	New physical servers in cloud	Virtualisation ratio – standard virtualised	Virtualisation ratio - cloud	Approx. Utilisation	Server power (unvirtualised) (W)	Server power (virtualised)
2010	20%	14%	4.0:1	10:1	60%	237	467
2011	25%	16%	4.0:1	10:1	60%	223	481
2012	31%	18%	4.0:1	10:1	60%	220	441
2013	36%	21%	5.0:1	10:1	60%	183	512
2014	38%	22%	5.0:1	10:1	60%	185	519
2015	40%	23%	5.0:1	10:1	60%	184	516
2016	40%	24%	5.5:1	10:1	60%	185	555
2017	41%	26%	5.5:1	10:1	60%	153	459
2018	41%	27%	5.5:1	10:1	60%	158	473
2019	42%	28%	5.5:1	10:1	60%	166	499
2020	42%	29%	5.5:1	10:1	60%	175	525
2021	42%	30%	5.5:1	10:1	60%	149	446
2022	42%	30%	5.5:1	10:1	60%	158	473
2023	42%	30%	5.5:1	10:1	60%	166	499
2024	42%	30%	5.5:1	10:1	60%	175	525
2025	42%	30%	5.5:1	10:1	60%	149	446
2026	42%	30%	5.5:1	10:1	60%	158	473
2027	42%	30%	5.5:1	10:1	60%	166	499
2028	42%	30%	5.5:1	10:1	60%	175	525
2029	42%	30%	5.5:1	10:1	60%	149	446
2030	42%	30%	5.5:1	10:1	60%	149	446

Server power and utilisation – Maximum Technical Savings scenario

Year	New physical servers virtualised	New physical servers in cloud	Virtualisation ratio – standard virtualised	Virtualisation ratio - cloud	Approx. Utilisation	Server power (unvirtualised) (W)	Server power (virtualised)
2010	20%	14%	4.0:1	10:1	60%	237	467
2011	25%	16%	4.0:1	10:1	60%	223	481
2012	31%	18%	4.0:1	10:1	60%	220	441
2013	36%	21%	5.0:1	10:1	60%	183	512
2014	38%	22%	5.0:1	10:1	60%	185	519
2015	40%	25%	5.0:1	10:1	60%	143	456
2016	40%	28%	6.0:1	10:1	60%	139	444
2017	40%	31%	6.0:1	10:1	60%	135	432
2018	40%	34%	6.0:1	10:1	60%	131	420
2019	40%	37%	6.0:1	10:1	60%	131	420
2020	40%	40%	6.0:1	10:1	60%	131	420
2021	40%	40%	6.0:1	10:1	60%	131	420
2022	40%	40%	6.0:1	10:1	60%	131	420
2023	40%	40%	6.0:1	10:1	60%	131	420
2024	40%	40%	6.0:1	10:1	60%	131	420
2025	40%	40%	6.0:1	10:1	60%	131	420
2026	40%	40%	6.0:1	10:1	60%	131	420
2027	40%	40%	6.0:1	10:1	60%	131	420
2028	40%	40%	6.0:1	10:1	60%	131	420
2029	40%	40%	6.0:1	10:1	60%	131	420
2030	40%	40%	6.0:1	10:1	60%	131	420

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