Association for Information Systems
AIS Electronic Library (AISeL)

ECIS 2014 Proceedings

GREENING DATA CENTRES: THE MOTIVATION, EXPECTANCY AND ABILITY DRIVERS

Alem Molla
RMIT University , Melbourne, Australia, alemayehu.molla@rmit.edu.au

Vanessa Cooper
RMIT University , Melbourne, Australia, vanessa.cooper@rmit.edu.au

Alem Molla and Vanessa Cooper, 2014, "GREENING DATA CENTRES: THE MOTIVATION, EXPECTANCY AND ABILITY DRIVERS", Proceedings of the European Conference on Information Systems (ECIS) 2014, Tel Aviv, Israel, June 9-11, 2014, ISBN 978-0-9915567-0-0
http://aisel.aisnet.org/ecis2014/proceedings/track22/2

GREENING DATA CENTRES: THE MOTIVATION, EXPECTANCY AND ABILITY DRIVERS

Complete Research

Molla, Alemayehu, School of Business IT and Logistics at RMIT University, Melbourne, Australia, alemayehu.molla@rmit.edu.au

Cooper, Vanessa, School of Business IT and Logistics at RMIT University, Melbourne, Australia, vanessa.cooper@rmit.edu.au

Abstract

Data centres are the backbone of the digital economy and the widespread adoption of cloud services, business analytics and big data will continue to accelerate their demand. Because data centres consume a significant amount of energy, research efforts are needed to identify what facilitates actions to implement practices and technologies to either retrofit to or architect green data centres. This paper address this issue drawing from institutional, expectancy and motivation–ability theories and based on survey data collected from 96 data centres. The findings indicate that performance and effort expectancy form the strong order drivers and together with ability will lead to the implementation of practices and technologies that improve the energy efficiency of data centres. In addition, institutional isomorphic forces serve as first order influences to shape expectations and trigger actions to develop skills and polices and to allocate financial resources that facilitate the implementation of greening practices. The paper further discusses a number of implications for research and practice.

Keywords*: Green IT, Data Centre, Energy Efficiency, Expectancy, Institution, Ability*

1 Introduction

Data centre operation represents the core of Information Technology (IT) function and large commercial data centres are growing to provide global cloud services. Although optimising hardware and power utilisation has been the concern of data centre management for a long time (Schmidt *et al.*, 2005), Gartner's (2006) and the United States Environmental Protection Agency's (EPA) (2007) reports highlighted the energy inefficiency and related CO_2 emissions of data centres. Estimates of data centre energy consumption and associated environmental impacts vary from one source to another. Globally, data centres are estimated to consume between 203 and 272 (TWh) or between 1.1% and 1.5% of total energy (Koomey *et al.*, 2013). Because of the recognition of data centres' environmental impacts, professional organisations such as the Uptime Institute, Green Grid and multilateral institutions such as the European Commission (EC), have produced code of conduct and practice guides that can potentially improve the operational performance (such as cost, uptime and disaster recovery), enhance the energy efficiency and reduce the environmental impacts of data centres (Accenture, 2008; EC, 2013). Three main reasons have motivated our investigation of the implementation of green practices in data centres.

First, although previous Green IT researchers have looked at isolated adoption of data centre practices such as virtualisation (Molla & Abareshi, 2012) and a few have focused on the adoption of information systems within data centres (Alaraifi *et al.*, 2012) and on case study driven conceptual frameworks (Karanasios *et al.*, 2010), so far we are not aware of a study that has provided a comprehensive investigation of the implementation of a range of technologies and practices covering both the IT and the power and cooling infrastructure of data centres. Some practitioner reports such as those by (Accenture, 2008; EC, 2013), opine that the wider use of various greening technologies has led (or can lead to) significant improvements in energy efficiency. But these studies do not explain what facilitates or inhibits implementation. This paper provides insights into data centre operators' actions to contribute to and/or compete on the basis of energy efficiency and environmental credentials.

Second, there is a general lack of IS research that focuses exclusively on data centres (Alaraifi *et al.*, 2013). As cloud based infrastructure as a service (Iaas) and recovery as a service (Rass) models move to mainstream adoption, research on data centres helps data centre owners and operators to identify and implement practices that improve both environmental credential and operational performance. It also helps clients of Iaas and Raas in choosing service providers. The study therefore advances IS research by nurturing diversity and extending "IS jurisdiction on organizational issues related to the adoption of systems and technologies" (Bernroider *et al.*, 2013, p. 86).

Third, much of Green IT adoption research draws from institutional (Chen *et al.*, 2010) motivational (Molla & Abareshi, 2012) and technology-organisation-environment (Alaraifi *et al.*, 2013; Bose & Luo, 2011) perspectives. These works have provided useful explanations about Green IT adoption and need to be extended to understand the interplay between different perspectives. In particular, the inherent cause-effect relationships among the institutional and organisational drivers are not sufficiently understood. In this paper, we integrate motivational-ability theory (Merton, 1968) with institutional theory (DiMaggio & Powell, 1983) including expectancy theory (Venkatesh *et al.*, 2003; Vroom, 1964).

The paper tackles the following three questions (1) what green practices (and to what extent) have data centre operators and owners implemented? (2) What drives the implementation of these practices? and (3) What relationships exist among the drivers? The rest of the paper is organised into background theory and hypotheses development, research methods, findings and discussion, and conclusion.

2 Background Theory and Hypotheses Development

The underpinning theory we used to investigate the implementation of green best practices in data centres is the motivation-ability theory. The motivation-ability theory – attributed to Merton (1968) postulates that a combination of organisational motivation and ability shapes the nature and intensity of actions. The theory is chosen because most, if not all, of the factors that influence innovation adoption relate to either the motivation for adopting or the ability of using innovations. Further the theory offers a generic framework to study different type and locus of motivations and abilities.

Motivations could be internal or external (Molla & Abareshi, 2012). To understand internal motives, we draw from the expectancy theory (Vroom, 1964). Expectancy theory, sometimes referred to as "VIE theory", depicts the relationship between valence (the value placed on the outcome), instrumentality (the likelihood that the outcome will be achieved if the performance expectation is met) and effort expectancy (the belief that effort will result in attainment of the desired performance. The theory is based on the notion that people choose to put their effort into activities that they believe they are capable of doing and which they believe will lead to desired outcomes. For external motives, we rely on the three institutional, that is, mimetic, normative and coercive forces (DiMaggio & Powell, 1983). The institutional theory provides a useful theoretical lens to understand the critical role played by institutional forces beyond the market in making organisations responsive to the interests of others. It also offers a rich and complex view of how organisations become homogeneous under pressure from external sources.

Organisational ability has been defined in a variety of ways and much research into organisational ability has taken a resource-based view, stressing the meshing of internal – human, technological and financial resources as well as know-how (how to do something) – leading to the creation of core competencies and competitive advantage in the market place (Grewal *et al.*, 2001). These resources and know-how shape the input based competencies required to implement an innovation. The remaining sub-sections develop the hypotheses by first starting with a description of practices and technologies for greening data centres.

2.1 Best Practices for Green(ing) Data Centres

There is no clear definition for a green data centre. A common approach used by industry and researchers is to describe the features of a green data centre and the practices, technologies and strategies that can improve the environmental footprint of a data centre (Schulz, 2009). Some characteristics of a green data centre include energy efficiency, minimum building footprints; maximum cooling efficiency; use of low-emission building materials, carpets and paints; installing catalytic converters on backup generators; and using alternative energy technologies such as photovoltaic electrical heat pumps and evaporative cooling (Accenture, 2008; Schulz, 2009). There are a number of practices (including technologies), and more might emerge in the future, that can be used to enable green data centres. Some of these are accepted as "best practices" because companies that have implemented them have achieved consistent results (Karanasios *et al.*, 2010). Categories of best practice have considered air management (e.g. liquid cooling, humidity systems, optimising and matching cooling to heat distribution load) (Karanasios *et al.*, 2010; Velte *et al.*, 2008); power management (e.g. optimising UPS, onsite power generation, lighting, efficient power transformation) (Green Grid, 2011; Velte *et al.*, 2008), computing management (stand-by facilities, environmentally friendly procurement, IT consolidation and virtualisation, optimising computing load and demand) (Green Grid, 2011; Karanasios *et al.*, 2010); facility design (right-size, room and building material) and infrastructure design (rack layout and monitoring) (Velte *et al.*, 2008).

2.2 Expectations for the Implementation of Green Data Centre Best Practices

An organisation's internal motives for green data centres refer to the effort and performance expectations of implementing green data centre best practices (Vroom, 1964). While performance and effort expectancy constructs are often examined in the context of IS adoption by individuals, captured in perceived usefulness and ease-of-use respectively (Venkatesh *et al.*, 2003), they are also relevant in organisational adoption of IS. For example, using five case studies, Wang et al (2006) adapted the Unified Theory of Adoption and Use of Technology (UTAUT) to investigate the adoption of business-to-business electronic marketplaces and found that performance expectancy is the most important consideration for adoption, whereas effort expectation (ease of use) was not considered a major factor given the technology investigated had matured. In another study based on diffusion of innovation, Tsai et al (2010) identified that relative advantage, complexity and organisational readiness significantly influence RFID adoption.

The constructs of performance and effort expectancy in organisational IS adoption, can be extended to the adoption of best practices for greening data centres. In this context, performance expectation considers the extent to which adopting best practices will result in improved operational and financial returns, as well as environmental return through reduction in energy use and emissions (EPA, 2007; Loper & Parr, 2007). Practices such as sourcing more efficient equipment, power management, server consolidation and virtualisation; rightsizing IT equipment and storage space; and cooling and thermal performance, have been found to reduce energy use and associated carbon emissions. However data centre managers are not always confident that such changes to operations will lead to savings (Loper and Parr, 2007). Further, data centre management has traditionally focused on availability, tolerance, reliability, performance uptime and an 'always on' mentality, rather than energy use and environmental impacts (Kant, 2009)), and this may reduce the perceived importance and thus usefulness of practices that focus on environmental performance. Thus:

> *Hypothesis 1: There is a positive association between the performance expectancy and the implementation of best practices for greening data centres.*

Effort expectancy refers to the perceived difficulty or ease of implementation of change or technology (Venkatesh *et al.*, 2003). Traditionally there has not been widespread availability of tools to model the energy consumption of data centres (Green Grid, 2007) making it difficult for a data centre manager to implement energy saving initiatives. A lack of holistic simulators to test the impact of a new resource (e.g. computing or cooling resource) in view of alternative data centre configurations (e.g. floor plans) has been a major obstacle to greening data centres (Gupta *et al.*, 2011). Data centres deploy a variety of hardware and software platforms and in most cases are housed in facilities that are not purpose built. This creates infrastructural inertia for implementing latest technologies and practices (Kant, 2009). Therefore whether the data centre is designed to be green from its conception, or retrofitted to be green will impact the perception of effort required to adopt green best practices (Green Grid, 2007). In addition, lack of detailed understanding and consideration by IT professionals regarding energy efficiency practices and technologies contributes to the perceived difficulty of implementing greening practices. Thus:

Hypothesis 2: There is a negative association between the effort expectancy (perceived difficulty) and the implementation of best practices for greening data centres.

The complexity of an IS has a negative relationship with the perceived performance benefits (Venkatesh *et al.*, 2003). For example, when users perceive mobile banking is easy to use, requiring little effort, they will have high expectations towards realising the expected performance returns, that is (Zhou *et al.*, 2010). By the same logic, if managers perceive that it is difficult to keep up with the latest technology and practices required to green their data centre, this may inhibit their perception of the operational and environmental advantages of doing so. Case study research undertaken by Karanasios *et al.* (2010) found that decisions around data centre energy efficiency takes place based on the range of performance consequences and effort. Therefore, organisations that perceive that greening their data centres will require a lot of effort will be less likely to perceive performance returns from doing so. This leads us to:

Hypothesis 3: There is a negative association between effort expectancy and the performance expectation of implementation of best practices for greening data centres.

2.3 Ability for the Implementation of Green Data Centre Best Practices

When knowledge barriers are high, adopter's ability to implement an innovation will be as relevant as their willingness to do so. Organisational ability includes awareness, knowledge, skill and experience that help businesses to recognise opportunities (Hostager *et al.*, 1998) as well as learning and capability (Grewal *et al.*, 2001). Organisational ability can therefore include organisational readiness and capability. Organisational readiness refers to an organisation’s stock of tangible (e.g. equipment, finance) and intangible capital (e.g. skills, patents) resources, while capabilities are the firm’s capacity in acquiring and utilising its resources to perform tasks and activities for competitive gain (Grewal *et al.*, 2001; Tsai *et al.*, 2010). By extension, an organisation’s ability to green its data centre includes the availability of stock of resources for supporting green IT initiatives, the knowhow of greening data centres as well as conducive managerial skills and organisational policies (Karanasios *et al.*, 2010).

Data centres are usually long-term investments and organisations may be unable to adopt more efficient and environmentally friendly technology due to resource constraints. Yet, in addition to budgetary constraints lack of knowledge and capacity are often cited as barriers to transitioning towards greener data centres (Loper & Parr, 2007). Therefore, ensuring IT staff have appropriate skills is central to whether an organisation is able to implement best practices for green data centres. Data centre managers have long been expected to keep up with complex technological change and innovation. The need to understand and address environmental outcomes, however, is a new requirement for many IT professionals —with sustainability considerations (e.g. strategy, management, assessment and engineering) having only been recently embedded into IT curricula and frameworks such as the Skills Framework for the Information Age[1]. IT staff that are up to date with the latest data centre technologies, and best practices for green data centres, will be in a better position to implement these within their organisation. Organisations that have developed their managerial capability, financial, policy and skills are more likely to develop positive attitude to implement best practices. On the basis of this, the following two hypotheses are formulated:

Hypothesis 4: Organisational ability positively influences the implementation of best practices for greening data centres.

[1] Source: http://www.sfia.org.uk /

Hypothesis 5: Organisational ability reduces (that is, negatively associated with) the perceived difficulty (effort expectancy) of implementing best practices for greening data centres.

2.4 Institutional Drivers, Expectancy and Ability

Institutional theory explains that mimetic, normative and coercive pressures that influence firm behaviour (DiMaggio and Powell, 1983) and is relevant in the context of organisational environmental initiatives and Green IT (Butler, 2011; Chen *et al.*, 2010). Mimetic pressures are evident when pressure to conform comes from other organisations and develops into an uncertainty-coping strategy (DiMaggio and Powell, 1983). Normative pressures are evident when cultural expectations compel organisations to legitimise their actions by conforming to established norms (DiMaggio and Powell, 1983). Coercive pressures are present when organisations act because of government laws and regulations (DiMaggio and Powell, 1983) and seek eco-legitimacy through meeting regulatory, political and social pressures (Chen et al., 2010). Institutional pressures have been found to directly influence Green IT/IS adoption (Chen et al 2010). Nevertheless, in this paper, in line with (Daly & Butler, 2009; Gholami *et al.*, 2013; Liang *et al.*, 2007), we chose to investigate if internal motives (expectation and ability) moderate data centres' acquiesce to institutional pressure to implement green best practices. Data centres that operate in an environment where green data centres are the norm, where greening data centre is promoted by industry and society, and where there is present or impending legislation on energy efficiency, are more likely to develop positive operational and environmental expectations of adopting green best practices. Thus:

Hypothesis 6: Institutional pressure positively contributes to the performance expectation of implementing best practices for greening data centres.

Success stories of organisations (such as Google) that have implemented and realised operational and environmental benefits from green data centre design and operation can create mimicking strategies in other organisations, trigger capability development and mitigate the perceived difficulty of implementing the best practices (Loper & Parr, 2007; Schulz, 2009). Coercive pressures affect all companies more or less the same way. As managers perceive the resulting actions as necessary evil, they might develop a positive attitude towards implementing green practices. On the other hand when environmental regulation is at a low level, the diffusion of green data centre practices can trace back to the imitation of competitors or trading partners leading to the following hypothesis:

Hypothesis 7: Institutional pressure reduces the effort expectancy of implementing best practices for greening data centres.

Further, the transition of many organisations to green data centres develops the knowledgebase and know-how of implementing best practices. It allows industry associations, professional bodies, government agencies and multilateral institutions to develop normative and prescriptive guidelines for operating data centres in as environmentally friendly manner as possible. Such relationships might provide opportunities for developing internal resources and capabilities and make the transition to best practices easier for those that follow through, avoiding common pitfalls (Cooper & Molla, 2012). The above argument leads us to:

Hypothesis 8: Institutional pressure positively contributes to organisational ability for implementing best practices for greening data centres.

3 Research Method

3.1 Measurement

The research deals with four variables – data centre best practices, institutional drives, expectancy motives, and ability. While the best practice is a formative variable the rest are reflective variables (see Appendix A). Twelve practices and technologies covering the IT and site (facility, cooling and power management) infrastructure of data centres were identified to measure green data centre best practices from Accenture (Accenture, 2008; EC, 2013). These twelve practices are amongst the list of data centre demonstration project initiatives and represent the best available technologies and practices for data centre energy efficiency (Accenture, 2008). Performance expectancy was measured using four indicators based on Loper and Parr (2007) who suggested that ensuring availability and recovery and reducing impacts and costs are key data centre operational considerations. Three items were pooled from Kant (2009) to tap into the perceived ex-ante difficulty of implementing best practices and technologies. Institutional drivers include coercive, mimetic and normative forces relevant to data centre operation. Nine items (three for mimetic, four for normative and two for regulative) were developed from Butler (2011), Chen *et al*. (2010), Daly & Butler (2009) and Kant (2009). Organisational ability is measured based on four items that tap into the stock of human and financial resources as well as managerial policy and support that create the input based competencies to implement best practices (Grewal *et al.*, 2001). Appendix A offers the list of items.

3.2 Data Collection and Response Rate

The sample for the survey was drawn from OneSource Australia— a commercial data base provider. Australian data centre operators, similar to European and USA operators, have come under increasing scrutiny for improving energy efficiency. Although we do not claim that the sample is representative of data centres globally, it provides useful examples of practices elsewhere. Since the research is intended to study data centres which are either separate business entities of their own, or, in most cases part of the IT departments of organisations, we requested Onesource for an initial count of “Data Centre Manager, IT Infrastructure Manager, IT Operations Manager, and ICT Director” job titles from their database. These job titles were selected after inspecting job titles of data centre groups on Linkedin.

Onesource provided an initial count of 2082 job titles. Further screening of the list (such as by removing duplicate titles) reduced the initial count to 1002. The 1002 contacts were invited to participate in an online survey, which was followed by five rounds of reminders. 194 respondents (19.45%) started the survey but only 164 (16.3%) progressed through the first page of which 97 usable responses (9.6%) were obtained. Most (77%) respondents had Data Centre Manager, IT Infrastructure Manager, or IT Operation Manager titles. 63% of the respondents were from government (33%), finance (14%) and the education and health (16%) sectors. Other responses came from the IT (7.3%), manufacturing (7.3%) and transport logistics (3.1%) sectors. The data centres vary in size from 10 to 1000 (average 326) installed servers. While some operate single data centres with (36.5%) or without (13.5%) dedicated facilities, the remaining (50%) operate multiple data centres in dedicated facilities.

3.3 Data Analysis

The data analysis proceeded in two steps of verifying the psychometric properties of the measurement model followed by the structural model test. SPSS and Smart PLS tools were used. To check if the data suffers from Common Method Bias (CMB), Harman’s single factor test was conducted. The single factor accounted for 26% of the variance in the data which is far less than the 50% threshold for CMB problem. To establish the construct validity of the measurement models of the reflective variables, first their factor structures were analysed. While ability, effort expectancy and performance expectancy were modelled as first order constructs, the institutional factor was modelled as a second order construct using the repeated indicator approach (Hair Jr *et al.*, 2014). Three items (EFFEX2, EFFEX3, PERFEX3) had to be dropped to achieve convergent and discriminant validity and reliability (Table 1 and 2).

The psychometric property of the formative construct was validated by following Hair et al’s (2014, pp. 131) procedure and evaluating the multicollinearity between indicators, the significance of the indicator weights and their absolute importance. First we conducted variance inflation factor (VIF) collinearity diagnostic and inspected the VIF and tolerance values. Since all VIF values are less than 5 and the tolerance values are greater than 0.2 (Table 1), there is no critical collinearity problem that affect the structural model. Second, we analysed the relative and absolute importance of the formative indicators and removed one item (BESTPRA9) because its outer weight is insignificant (no relative importance) and it has a <0.5 and insignificant outer loading (no absolute importance).

Variable	Type	Item[2]	Loadings /weights[3]	AVE	CR	alpha	VIF	Tolerance
Ability	Reflective	AGITG3	0.76	0.57	0.87	0.81		
		AGITG4	0.87					
		AORGC2	0.67					
		ASKILL1	0.66					
		ASKILL2	0.82					
Effort Expectancy	Reflective	EFFEX1	0.77	0.66	0.79	0.70		
		EFFEX4	0.85					
Performance expectancy	Reflective	PREFEX1	0.79	0.56	0.79	0.70		
		PREFEX2	0.81					
		DCOP3	0.62					
Institutional-mimetic	Reflective	MIMIC1	0.85	0.79	0.92	0.86		
		MIMIC2	0.90					
		MIMIC3	0.91					
Institutional-normative	Reflective	NORM1	0.83	0.67	0.89	0.83		
		NORM2	0.74					
		NORM3	0.87					
		NORM4	0.84					
Institutional regulative	Reflective	REGLT1	0.92	0.83	0.91	0.79		
		REGLT2	0.90					
Best Practice	Formative	BESTPRA1	0.35	NA	NA	NA	2.92	0.34
		BESTPRA2	0.47				3.32	0.30
		BESTPRA3	0.38				3.88	0.26
		BESTPRA4	0.73				2.10	0.48
		BESTPRA5	0.80				2.24	0.45
		BESTPRA6	0.51				1.55	0.64
		BESTPRA7	0.53				1.80	0.56
		BESTPRA8	0.58				1.58	0.63
		BESTPRA10	0.63				2.08	0.48
		BESTPRA11	0.53				2.38	0.42
		BESTPRA12	0.32				2.73	0.37

Table 1: Construct validity and reliability

[2] *EFFEX2, EFFEX3, PERFEX3,BESTPRA9 were deleted during the instrument validation process*
[3]*For reflective scales, the standardised loading is provided; for formative scales, the weight is given*

	1	2	3	4	5	6
1 .Ability	**0.76**[4]					
2. Effort expectancy	-0.34	**0.81**				
3. Mimetic	0.31	-0.16	**0.89**			
4. Normative	0.45	-0.08	0.77	**0.82**		
5. Performance expectancy	0.26	-0.23	0.62	0.61	**0.75**	
6. Regulative	0.39	-0.12	0.63	0.72	0.57	**0.91**

Table 2: Discriminant validity of first order reflective constructs

To test the structural model and estimate the significance of the path coefficients, 5000 sample bootstrapping was performed. The result is in Figure 2. The model explains 51% of the variance in the implementation of green data centre practices and has a medium predictive relevance ($q^2 = 0.17$).

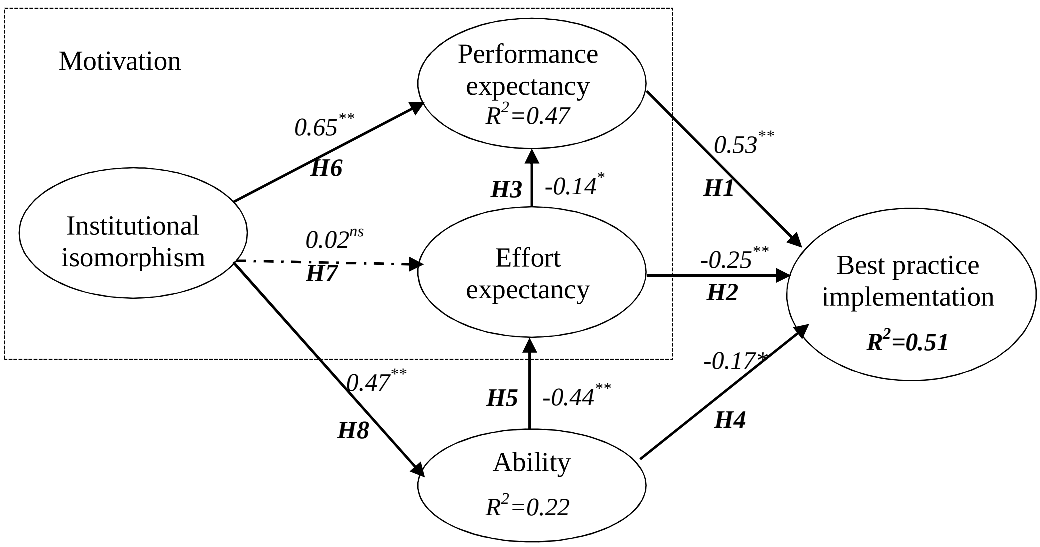

Figure1: Structural model result[5]

4 Findings and Discussion

The findings and discussions are structured around the three research questions.

4.1 Extent of Green Practices Implementation in Data Centres

The implementation extent of twelve practices and technologies (all items are included in the descriptive analysis), of which seven belong to the IT infrastructure and the remaining to the facility infrastructure, were evaluated. The result shows that the most widely implemented technologies and practices belong to the IT infrastructure domain rather than the facility domain. In particular, while most data centres have either aggressively or moderately virtualised (81%), consolidated (78%) eliminated unused (72%) and acquired energy efficient (60%) servers, and some have taken actions in terms of the power management of servers and applications as well as upgrading to energy efficient transformers and UPS, less than one

[4] *Diagonal values are square root of AVE*
[5] ***, p<0.01; *, p<0.05*

third have implemented technologies that improve energy levels consumed in cooling data centres. Nearly 70% and 82% of the respondents have yet to implement free cooling and liquid cooling respectively, which shows a potential for further energy saving opportunities amongst Australian data centres. The next two sections explain the reasons behind this observation.

4.2 Drivers of Green Practices Implementation among Data Centres

We hypothesized that while performance expectancy, effort expectancy and ability directly influence the implementation of best practices, institutional factors have indirect influence. There is a significant relationship (β= 0.53, $p<0.01$) between performance expectancy and best practice implementation thus support for ***hypothesis 1***. Performance expectancy has a large effect size (f^2=0.43) implying that the implementation of green data centre practices is strongly influenced by both financial, disaster recovery and environmental return expectations, of which the large majority of respondents (71%) identify disaster recovery as the main and most important reason for implementing best practices. This corroborates Sayeed and Gill's (2010) case study which identified cost cutting and energy conservation as the main reasons for undertaking Green IT initiatives, as well as Molla and Abrashie's (2012) analysis which showed that organisational desire to improve sustainability while at the same time pursuing cost cutting objectives drive the adoption of Green IT. It is also in line with Wang et al's (2006) conclusion that firms' electronic market adoption decision was less affected by effort expectancy of users. This means while financial performance expectation is common to all IT initiatives, Green IT investments are expected to meet the dual objectives of both green and non-green performance expectations.

The support of ***hypothesis 2*** (β= -0.25, $p<0.01$) shows that data centres opt for green best practices implementation when efforts are manageable. 53% and 42% of respondents believe that changing their existing data centre to green data centre and keeping up with latest data centre best practices is difficult. However effort expectancy has a small effect (f^2=0.10). Facility design constraints affect the suitability of adopting innovations such as free cooling. For example, data centre facilities that are not purpose-built have faced limitations in accommodating different cooling techniques, such as non-raised floor rooms (where cooling is supplied from the ceilings and exhausters located near the walls) or raised floor rooms (where the chilled air is circulated under the raised floor) (Kant, 2009).

Moreover, support for ***hypothesis 4*** (β= 0.27, $p<0.05$) shows that resource allocation for green IT, increasing skills of data centre professionals, as well as organisational wide awareness about the impact of IT and energy efficiency opportunities, motivate the implementation of best practises. Thus while nearly 50% of respondents agree that their IT professionals are skilled in data centre technologies, only 17% agree that their professionals are skilled in green data centre best practices. Further only 12%, 18% and 24% of the respondents believe that their organisations have allocated Green IT budget, have developed clear policies for improving data centre energy consumption, and developed awareness about the environmental impact of IT operations.

Because the research model consists of variables derived from institutional and expectancy theories, we explored two independent models– institutional only and expectancy only. While the institutional only model explained 33% of the variance with a significant path (β= 0.57, $p<0.01$), the expectancy only model explains 49% of the variance and the paths from performance and effort expectancy to green best practices implementation are significant (β= 0.58, $p<0.01$ and β= 29, $p< 0.01$ respectively). This suggests that current drivers of best practices implementation among data centres have more to do with performance and effort expectation and less with institutional factors. The following section discusses the remaining hypotheses on the relationship between the first and strong order drivers and ability.

4.3 Relationships among Green data centre drivers

A number of studies have reported that institutional factors have direct influence on technology adoption including Green IT and Green IS (Chen *et al.*, 2010). In this study, we hypothesised that institutional forces are external drivers that are essential to trigger internal drivers of performance and effort expectation as well as the development of organisational ability which lead to implementation of greening practices. The research model explains 47% of the variance in performance expectancy. Both institutional forces (β=0.65, $p<$ 0.01) and effort expectancy (β= -0.14, $p<$0.01) are significantly related to performance expectancy, thus supporting ***hypotheses 3 and 6***. However, of the two variables, institutional forces have a significantly large (f^2= 0.79) effect size on performance expectancy compared to effort expectancy. This means coercive isomorphism in the form of current and foreseeable government regulations and incentives; mimetic isomorphism created through success stories from early adopters including competitors and suppliers, as well as normative isomorphic effects established through industry norms, certifications, acknowledgements and standards, contribute to favourable performance expectation. This finding extends the result of Gholami *et al*. (2013) on the relationship between institutional fields and managerial attitude to Green IS adoption and provides empirical support. When governments enforce tighter regulations and monitoring activities, and when early movers and trend setting organisations showcase the value of implementing data centre technologies and practices, they shape the perceived environmental, financial and disaster recovery benefits of implementing those practices. The significant relationship between effort expectancy and performance expectancy is consistent with Venkatesh et al (2003).

On the other hand, institutional forces strongly influence organisational ability (β= 0.43, $p<$ 0.01) but do not seem to have any direct and significant relationship with effort expectancy (β= -0.02 p= ns), thus while ***hypothesis 8*** is supported, ***hypothesis 7*** is not. When the path from ability to effort expectancy is removed and the model is re-run, the path between institutional forces and effort expectancy become significant (β= -0.14, $p<$0.05). This leads us to deduce that the influence of institutional forces on effort expectancy is fully mediated by ability. This means when institutional isomorphism is stronger it puts pressure on organisations to develop skills and policies and allocate financial resources. Moreover, organisational ability contributes to reducing the perceived difficulty of adopting and extending the use of a particular practice among data centres. Thus ***hypothesis 5*** (β= -0.14, $p<$0.05) is supported.

5 Conclusion, Contribution and Limitation

Data centres are the backbone of the digital economy and the adoption of cloud services and big data will accelerate their demand. For example, Australia's federal government uses 30,000 square metres of data centre space, spends an estimated $850 million per annum on data centres, of which 170 million is on electricity[6]. Globally, because data centres consume a significant amount of energy, research efforts are needed to identify what facilitates actions to implement best practices and technologies to either retrofit or architect green data centres. This paper addressed this issue and makes a number of contributions.

First, this paper shows what actions organisations are taking to improve energy efficiency and to apply environmental sustainability considerations in their data centres. The two components that consume the most energy in data centres are the IT equipment and cooling systems. Our findings tell that data centre managers can follow either tactical-incremental or deep-green strategies to manage the implementation of green practices. Those that follow tactical-incremental strategy can focus on initiatives to reduce the headcount of servers through virtualisation and consolidation efforts. These initiatives are less constrained by infrastructural inertia, are easy to showcase cost savings with proven return on investment and are relatively less complex to implement thus are less risky. This strategy will lead to moderate benefits and green goals and on its own is unlikely to reduce data centres' growing demand for energy.

The deep-green strategy expands the measures of the tactical-incremental strategy to fundamentally redesign data-centres in a way that neutralises greenhouse gas emissions covering the IT, power delivery and cooling systems. While such approach is highly feasible for architecting new data centres, it requires

[6] *http://www.finance.gov.au/files/2012/04/AGDC_Strategy.pdf*

demonstrable benefits from the adoption of tactical-incremental strategy for retrofitting existing data centres. Most data centres use air-cooling, that is, chilled water from either a chillier or refrigeration system, to keep an ambient-temperature of the data centre room. Such systems generally consume a lot of energy. Free cooling on the other hand uses an air-side economiser to harvest outside air, whenever it is possible, and deliver cool air directly to the demands of the IT equipment, thus shutting off the chillier system and saving energy consumption (Ohadi *et al*., 2012). Likewise liquid cooling, which uses water or other liquids to transfer heat away from the server components, is estimated to be 3500 time more energy efficient than conventional air-cooling systems (Ohadi *et al.*, 2012). The implementation of these practices requires a deep-green strategy

Second, in order to gain support for green best practice implementations from within the organisation, data centre managers have to align their greening efforts with corporate sustainability initiatives. Green data centre practices are relatively new and due to the lack of experience, there is scepticism about their value to justify investment. In order to demonstrate value, mangers should focus on tactical-incremental proof-of concept projects. In addition, they would need to use the experiences of firms that have adopted greening technologies and the positive benefits achieved because of these actions to shape the performance and effort belief formation processes within their organisations. In addition, measuring the energy performance of the different components of data centres is different from conventional work related IS. In conventional work related IS, the issue of measurement is handled by accounting systems. In energy management, the measurement systems have to be built from the scratch. Therefore mangers need to define metrics and indicators for measuring data centre’s energy consumption. Such practices will get better traction when data centre managers are held accountable for energy performance.

Third, the theoretical model explains approximately 51% of the variation (with medium predictive relevance) in the implementation of green practices and 47% of the variance (again with medium predictive relevance) in the formation of performance expectations. For comparison, Liang et al’s (2007) study of ERP assimilation; Zhu and Kraemer’s (2005) investigation of post adoption variation in e-business use; Chen et al’s (2010) institutional theory driven analysis of green IT/IS adoption and Molla and Abareshi’s (2012) motivational theory based exploration of green IT adoption explained 39%, 20%, 36% and 50% of the variance respectively. This implies that the theoretical model has performed better than previous studies and with the necessary adaptation of the measurement items can be used in future studies of emerging IS/IT (including Green IS and IT) adoptions.

Fourth, the paper shows how different motives interrelate among one another. Particularly, it shows that institutional forces contribute to the formation of managerial expectations and the development of organisational ability and how this leads to action. This logic offers researchers alternative theoretical perspectives in understanding Green IT and IS implementations among organisations. To practitioners, the paper extends those industry reports by helping to understand not only the best practises but also what leads to their implementation.

We note four limitations of the study that open avenue for further studies. First, the sample frame was sourced from a single country. Second, in terms of the nature of data centres, our sample was skewed towards single tenant data centres, that is, data centres that are part of the IT departments of organisations rather than multi-tenant, that is, data centres that operate as independent business entities. We did not have enough samples to test differences between these two groups. But we expect that the relationship we have established might hold true as the performance drivers are even stronger for business entity data centres. Testing this model on a global sample comprised of multi-tenant data centres providers additional insights. In addition, because of space constraints, we didn’t include the effect of controlling variables such as size, age and industry differences among data centres. Third, the paper is based on a cross-sectional survey, which does not allow for the evaluation of the long-term impact of implementing the best practices. Fourth, one part of expectancy theory point out that effectiveness itself creates further motivation to follow the policies. This dimension of the theory is not tested in this paper. As such, the current analysis did not go far enough to evaluate if the ex-ante operational and environmental performance expectations have been realised and the effectiveness of implementing the green practices which will be the subject for further research.

6 References

Accenture. (2008). Data Center Energy Forecast Final Report. http://www.accenture.com/us-en/Pages/insight-data-center-energy-forecast-report.aspx

Alaraifi, A., Molla, A, & Deng, H. (2013). An Empirical Analysis of Antecedents to the Assimilation of Sensor Information Systems in Data Centers. *International Journal of Information Technologies and Systems Approach (IJITSA), 6*(1), 57-77.

Alaraifi, A., Molla, A.., & Deng, H. (2012). An Exploration of Data Center Information Systems. *Journal of Systems and Information Technology, 14*(4), 353-370.

Bernroider, WN., Pilkington, A., & Cordoba, J. (2013). Research in information systems: a study of diversity and inter-disciplinary discourse in the AIS basket journals between 1995 and 2011. *Journal of Information Technology, 28*(1), 74-89.

Bose, R., & Luo, X. (2011). Integrative framework for assessing firms' potential to undertake Green IT initiatives via virtualization - A theoretical perspective. *The Journal of Strategic Information Systems, 20*(1), 38-54. doi: 10.1016/j.jsis.2011.01.003

Butler, T. (2011). Compliance with institutional imperatives on environmental sustainability: Building theory on the role of Green IS. *The Journal of Strategic Information Systems, 20*(1), 6-26. doi: DOI: 10.1016/j.jsis.2010.09.006

Chen, A.J., Watson, R.T., Boudreau, M.C., & Karahanna, E. (2010). An institutional perspective on the adoption of Green IS & IT. *Australasian Journal of Information Systems, 17*(1), 23-45.

Cooper, V., & Molla, A. (2012). *A contextualist analysis of Green IT learning in organisations*. Paper presented at the International Conferenece on Information Resource Management, Vienna, Austria. http://aisel.aisnet.org/confirm2012/36/

Daly, M., & Butler, T. (2009). *Environmental Responsibility and Green IT: An Institutional Perspective*. Paper presented at the 17th European Conference on Information Systems Verona, Italy

DiMaggio, P.J., & Powell, W.W. (1983). The Iron Cage Revisited: Institutional isomorphism and collective rationality in organizational fields. *American sociological review, 48*(2), 147-160.

EC. (2013). *2013 Best Practices for the EU Code of Conduct on Data Centers*. Retrieved from http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/best_practices_v4_0_5.pdf

EPA. (2007). Report to Congress on Server and Data Centre Energy Efficiency, Public Law 109 - 732. http://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf

Gartner. (2006, November 28 - December 1). *50 Percent of Data Centers Will Have Insufficient Power and Cooling Capacity by 2008.* Paper presented at the 25th Annual Gartner Data Center Conference, Las Vegas, USA.

Gholami, R. , Sulaiman, A., Ramayah, T B., & Molla, A. . (2013). Senior Management Perception on Green Infomration Systems Adoption and Environmental Performance: Results From a Field Survey. *Information and Management, 50*(7), 431-438. doi: http://dx.doi.org/10.1016/j.im.2013.01.004

Green Grid. (2007). Guidelines for Energy-Efficient Data centers Retrieved Nov. 13, 2013 from http://www.thegreengrid.org/Global/Content/white-papers/Green-Grid-Guidelines

Green Grid. (2011). Data Center Maturity Model Retrieved Nov 13, 2013 from http://www.thegreengrid.org/en/Global/Content/Tools/~/media/Tools/DataCenterMaturityModelv1.ashx

Grewal, R., Comer, J.M., & Mehta, R. (2001). An Investigation into the Antecedents of Organizational Participation in Business-to-Business Electronic Markets. *Journal of Marketing, 65*(3), 17-33.

Gupta, S.KS, Gilbert, R.R, Banerjee, A., Abbasi, Z., Mukherjee, T., & Varsamopoulos, G. (2011). *GDCSim: A tool for analyzing green data center design and resource management techniques*. Paper presented at the Green Computing Conference and Workshops (IGCC), 2011 International. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6008612

Hair Jr, J. F, Hult, G. T.M, Ringle, C. M, & Sarstedt, M. (2014). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Thousand Oaks, California: Sage Publications Inc.

Hostager, T. J, Neil, T.C, Decker, R.L, & Lorentz, R.D. (1998). Seeing environmental opportunities: effects of intrapreneurial ability, efficacy, motivation and desirability. *Journal of Organizational Change Management*, *11*(1), 11-25.

Kant, K. (2009). Data Center Evolution:: A Tutorial on State of the Art, Issues, and Challenges. *Computer Networks*, *53*(17), 2939-2965.

Karanasios, S., Cooper, V., Deng, H., Molla, A., & Pittayachawan, S. (2010). *Antecedents to Greening Data Centres: A conceptual framework and exploratory case study*. Paper presented at the Proceedings of the 21st Australasian Conference on Information Systems, Brisbane.

Koomey, J.G, Matthews, H.S., & Williams, E. (2013). Smart Everything: Will Intelligent Systems Reduce Resource Use? *Annual Review of Environment and Resources, 38*(1), 311.

Liang, H., Saraf, N., Hu, Q., & Xue, Y. (2007). Assimilation of enterprise systems: The effect of institutional pressures and the mediating role of top management. *Management Information Systems Quarterly, 31*(1), 6.

Loper, J, & Parr, S. (2007). Energy Efficiency in Data Centers: A New Policy Frontier. *Environmental Quality Management*, *16*(4), 83-97.

Merton, R.K. (1968). *Social Theory and Social Structure*. New York: Free Press

Molla, A., & Abareshi, A. (2012). Organizational Green Motivations for Information Technology: Empirical Study. *Journal of Computer Information Systems*, *52*(3), 92-102.

Ohadi, MM., Dessiatoun, SV., Choo, K., Pecht, M., & Lawler, JV. (2012). *A comparison analysis of air, liquid, and two-phase cooling of data centers*. Paper presented at the Semiconductor Thermal Measurement and Management Symposium (SEMI-THERM), 2012 28th Annual IEEE. 10.1109/STHERM.2012.6188826

Sayeed, L., & Gill, S. (2010). An exploratory study on organisational adjustments due to Green IT. *International Journal of Management and Enterprise Development*, *9*(3), 233-250.

Schmidt, R.R., Cruz, E.E., & Iyengar, M.K. (2005). Challenges of Data Center Thermal Management. *IBM Journal*, *49 (4/5)*, pages (709-723).

Schulz, G. (2009). *The Green and Virtual Data Center*. FL: CRC Press, Taylor & Francis

Tsai, M-C, Lee, W., & Wu, H-C. (2010). Determinants of RFID Adoption Intention: Evidence from Taiwanese Retail Chains. *Information & Management*, *47*(5), 255-261.

Velte, T., Velte, A., & Elsenpeter, R. C. (2008). *Green IT: reduce your information system's environmental impact while adding to the bottom line*: McGraw-Hill, Inc.

Venkatesh, V., Morris, M.G., Davis, G.B., & Davis, F.D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

Vroom, V. H. (1964). *Work and Motivation*. New York Wiley.

Wang, S., Archer, N. P, & Zheng, W. (2006). An Exploratory Study of Electronic Marketplace Adoption: a Multiple Perspective View. *Electronic Markets*, *16*(4), 337-348.

Zhou, T, Lu, Y, & Wang, B. (2010). Integrating TTF and UTAUT to Explain Mobile Banking User Adoption. *Computers in Human Behavior*, *26*(4), 760-767.

Zhu, K, & Kraemer, K.L. (2005). Post-adoption Variations in Usage and Value of E-business by Organizations: Cross-country Evidence From the Retail Industry. *Information Systems Research*, *16*(1), 61-84.

Appendix A: Survey Items

Variable	Definition	Items and scale	References
Green Data Centre Best Practice	Technology and practice guidelines that are vetted by industry bodies and other institutions for greening data centres	BESTPRA1: Server virtualisation BESTPRA2: Server consolidation BESTPRA3: Storage consolidation BESTPRA4: Adoption of "energy-efficient" servers BESTPRA5: Enable power management of all applicable servers BESTPRA6: Eliminate unused servers (e.g., legacy applications) BESTPRA7: Enable Data Centre level power management of applications, networking and storage equipment BESTPRA8: Airflow management BESTPRA9: Liquid cooling BESTPRA10: More efficient transformers and or/UPS BESTPRA11: More efficient chillers, fans, and pumps BESTPRA12: Free cooling *Scale: Four point scale: no, little, moderate and aggressive implementation*	(Accenture, 2008; EC, 2013; EPA, 2007; Schulz, 2009)
Institutional drives	Data centre specific mimetic, normative and regulative drivers	REGLT1: Current and foreseeable government regulations (e.g. NGERS, ETS etc) REGLT2: Government incentives (energy efficiency opportunities) MIMIC1: Competitors' extent of implementation MIMIC2: Success stories of others who have implemented MIMIC3: Suppliers'/customers' extent of implementation NORM1: Green Data Centre certifications NORM2: Current and foreseeable Data Centre standards NORM3: Publicity about Data Centre energy consumption NORM4: Encouragement from industry associations *Scale: Five point likert scale not considered to strong reason*	(Butler, 2011; Chen *et al.*, 2010; Daly & Butler, 2009; Kant, 2009)
Performance expectancy	Ex-ante expectation of returns from investments in technologies and practices	PERFEX1: Financial return (cost saving) on investment PERFEX2: Environmental return (energy, emission, waste, water reduction) on investment PERFEX3: Improves uptime DCOP3: Disaster recovery *Scale: Five point ranging from not considered to strong reason*	(Loper & Parr, 2007)
Effort expectancy	Data centre managers' ex-ante expectation of difficulties in implementing best practices and technologies	EFFEX1: Changing our existing data centre to green data centre is difficult EFFEX2: Our current data centre facilities limit the implementation of best practices EFFEX3:Implementing data centre best practices requires a significant effort EFFEX4: It is difficult to keep up with latest data centre best practices *Scale: Five point likert from strongly disagree to strongly agree*	(Kant, 2009)
Ability	Input based organisational, human & financial competencies	AORGC2: There is company-wide awareness on the role of IT in causing and solving environmental problems ASKILL1:Our IT personnel are skilled in latest data centre technologies ASKILL2: Our IT personnel are skilled in green data centre best practices AGITG3: Budgets are allocated for Green IT initiatives AGITG4: We have a clear organisational policy on improving data centre energy consumption *Scale: Five point scale from strongly disagree to strongly agree*	(Grewal *et al.*, 2001)