A MATURITY MODEL FOR ENERGY EFFICIENCY IN MATURE DATA CENTRES

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Abstract: Data centres are complex eco-systems that interconnect elements of the ICT, electrical, and mechanical fields of engineering and hence the efficient operation of a data centre requires a diverse range of knowledge and skills from each of these fields. The Innovation Value Institute (IVI), a consortium of leading organizations from industry, the not for profit sector, and academia, have developed a maturity model that offers a comprehensive, value-based method for organizing, evaluating, planning, and improving the energy efficiency of mature data centres. The development process for the maturity model is discussed, detailing the role of design science in its definition.

1. INTRODUCTION

According to McKinsey & Co. (Forrest & Kaplan, 2008) the world's 44 million servers consume 0.5% of all electricity and produce 0.2%, or 80 megatons, of carbon dioxide emissions a year. Given a business as usual scenario, by 2020 greenhouse gas emissions from Data Centres (DCs) are projected to more than double from 2007 levels (Webb, 2008). The efficient operation of a data centre requires a diverse range of knowledge and skills from a large ecosystem of stakeholders. A DC requires expertise from engineering (including electrical, civil, mechanical, software, and electronic) to accountancy to systems management. The Innovation Value Institute (IVI), a consortium of leading organizations from industry (including, Microsoft, Intel, SAP, Chevron, Cisco, The Boston Consultancy Group, Ernst & Young, and Fujitsu), the not for profit sector, and academia, has developed and tested a maturity model for systematically assessing and improving *energy efficient* capabilities within mature DCs. The model offers a comprehensive, value-based model for organizing, evaluating, planning, and managing DC capabilities for energy efficiency and fits within IVI's IT-Capability Maturity Framework (IT-CMF) for managing IT. The model provides a high-level assessment of maturity for IT managers with responsibility for DC operations.

2. DC ENERGY COMSUMPTION

Power usage within a DC goes beyond the direct power needs of servers to include networking, cooling, lighting, and facilitie. Power draws for DCs range from a few kilowatts for a rack of servers to several tens of megawatts for large facilities. While the exact breakdown of power usage will vary between individual DCs, Figure 1 illustrates the examination of one DC where up to 88.8% of the power consumed by the DC was *not* used on computation (U.S. EPA, 2007). International Data Corporation (IDC) estimates that DC energy costs will be higher than equipment costs by 2015 (Martinez & Bahloul, 2008). The cost of operating a DC goes beyond the economic bottom line; there is also an environmental cost. DCs are the fastest growing contributor to the IT sectors environmental footprint and are predicted to grow to 259 MtCO2e by 2020, up from 76 MtCO2e in 2002 (Webb, 2008).

3. DC ENERGY EFFICIENCY

With electricity costs being the dominant operating expense of a DC, it is vital to maximize the operational efficiency in order to reduce both the environmental and economic cost. Energy efficient DC operations require a holistic approach to both IT and facilities energy management. DC and IT leaders are often unable to find satisfactory answers to questions such as:

- What is the utilization of the DC?
- How energy efficient is the DC?
- Are there clear measurable goals and objectives for DC energy efficiency (EE)?
- What is the roadmap for DC EE improvements?

IT departments face additional challenges – such as the introduction of new methods and tools, and conformance to industry metrics and standards – which are compounded by a general lack of relevant information, such as power consumption quantifications. Mature DCs typically have a heterogeneous IT infrastructure with fixed support systems, making it arduous to employee catch-all solutions.

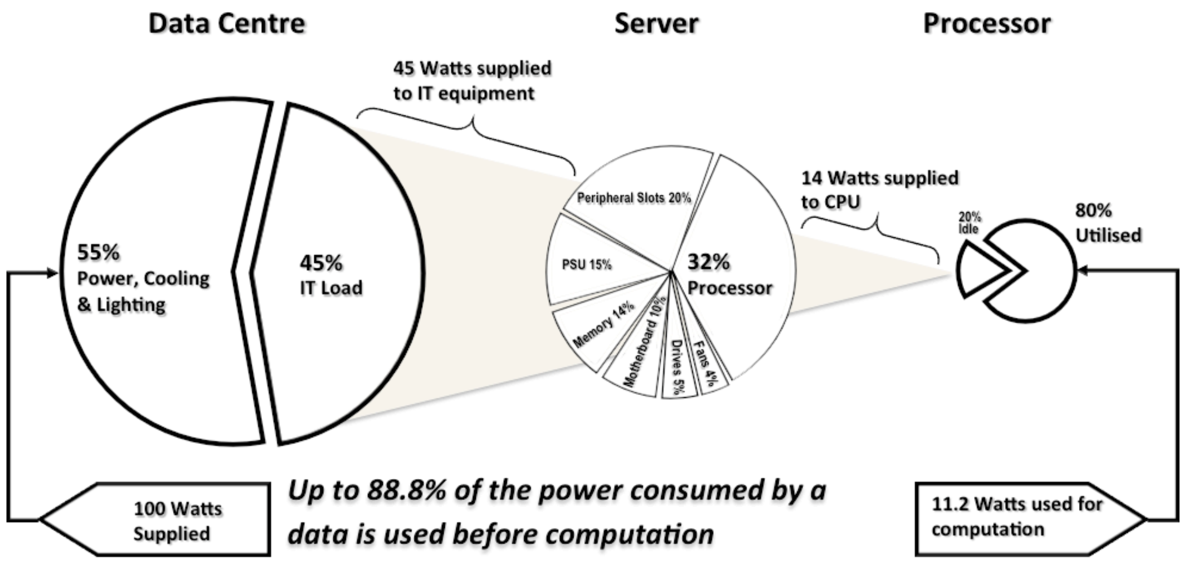

Figure 1. Example breakdown of power usage within a Data Centre

4. THE NEED FOR A MATURITY MODEL

Maturity models are tools that have been used to improve many capabilities within organizations, from Business Process Management (BPM) (Rosemann & De Bruin, 2005) to Software Engineering (CMMI) (Paulk, Curtis, Chrissis, & Weber, 1993). Maturity models have also been developed to support the management of IT organizations. IVI have developed the IT-Capability Maturity Framework (IT-CMF) (Curley, 2004) that provides a high-level process capability maturity framework for managing the IT function within an organization to deliver greater value from IT by assessing and improving a broad range of management practices. A core function of IT-CMF is to act as an assessment tool and a management system.

There is a need to improve the behaviours, practices, and processes within DCs in order to deliver greater energy efficiency. To address this need, the IVI consortium has extended the IT-CMF with a maturity model for systematically assessing and improving DC capabilities for energy efficiency.

4.1 Design Methodology

The development of the model was undertaken using a design process with defined review stages and development activities based on the Design Science Research (DSR) guidelines advocated by Hevner et al. (Hevner, March, Park, & Ram, 2004). During the design process, researchers participate together with practitioners within a working group to research and develop the model. The working group interviewed multiple DC stakeholders to capture the views of key domain experts and to understand current practice and barriers to improving DC energy efficiency (EE). The working group widely consulted the relevant literature, both industrial and academic, on DC EE. Industrial best practices – including the EU code of conduct for DC EE and the work of the Green Grid on metrics – were incorporated. The initial maturity model was developed in mid-2010 and has been piloted within a number of DCs, with learning and feedback incorporated into subsequent versions.

5. MATURITY MODEL

The Data Centre EE model offers a comprehensive, value-based model for organizing, evaluating, planning, and managing DC EE capabilities. The model fits within IT-CMF (Curley, 2004) and is aligned with the broader Sustainable ICT critical capability (Curry & Donnellan, 2012; Donnellan, Sheridan, & Curry, 2011).

The DC EE assessment methodology determines how different DC capabilities are contributing to energy efficiency goals and objectives. The gap analysis between what energy efficiency targets are, and what they are actually achieving, positions the Data Centre EE model as a management tool for aligning relevant capabilities with EE objectives. The model focuses on the execution of four key actions to improve the management of EE in the DC:

- Define goals and objectives for the DC program
- Understand the current DC maturity level,
- Systematically develop and manage the DC capability building blocks.
- Assess and manage DC progress over time.

5.1 Capability Building Blocks

The Data Centre EE model consists of seven capability building blocks (see Table 2) in the categories of Management, Operations, and Building. The maturity level for each of the seven Capability Building Blocks is presented in Table 1.

Table 2: Capability Building Blocks of Energy Efficicent Data Centres

	Capability	Description
Management	Organizational Structure	How the data centre and its energy efficiency is managed, who is responsible for running the DC, and how integrated are: IT, Facilities, and the Business.
	Policy	The policies in place for energy efficiency within the the DC and how they are aligned across the enterprise.
	Manageability and Metering	The metering use by IT and Facilities to improve understanding and manageability of energy usage.
Operations	IT Infrastructure and Services	The management of IT equipment and services to ensure energy efficiency.
Building	Internal Air and Cooling	The internal air manageemnt techniques employed.
	Cooling Plant	The design and management of the cooling system.
	Power Infrastructure	The management of power generation, and conditioning and delivery systems to maximize energy efficiency.

5.2 Assessment Approach

The assessment begins with an online survey of DC stakeholders in order to understand their individual assessments of the maturity and the importance of these capabilities. Typically, a range of individuals who are involved in, or accountable for, EE for the DC complete the survey. A series of targeted interviews with key stakeholders augments the survey to understand key business priorities and energy efficiency drivers, successes achieved, and initiatives taken or planned. Interviews last between 60 and 90 minutes; they are used to support the survey data.

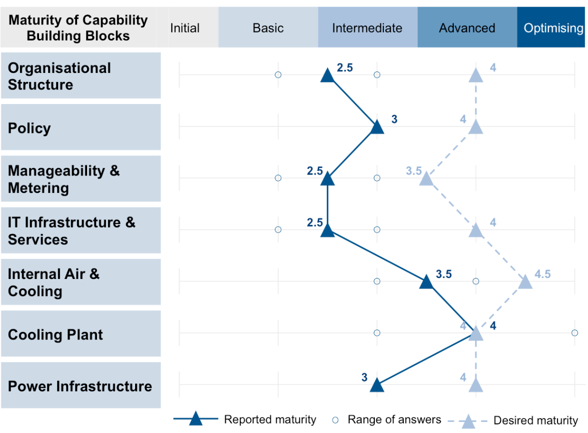

Figure 2. Reported vs. Desired Maturity

When the assessment is complete, organizations will have a clear view of current capability and key areas for action and improvement. A smaple pilot assessment result in illustrated in Figure 2. However, to further develop the capability, the organization should assess and manage progress over time by using the assessment results to 1) develop a roadmap and action plan and 2) add a yearly/half-yearly follow-up assessment to the overall DC energy efficiency management process.

6. SUMMARY AND FUTURE WORK

The IVI consortium has developed and tested a maturity model for systematically assessing and improving Energy Efficient capabilities within mature Data Centres. The resulting model offers a comprehensive, value-based model for organizing, evaluating, planning, and improving the energy efficiency of mature data centres. Further development and evaluation of the model is planned – in particular, the use of the model in conjunction with metrics such as PUE, CUE, WUE, and CapEx/OpEx costs – in order to quantify benefits. We are also employing the model to benchmark DCs within the IVI consortium to faciliate comparisons between DCs across and between industrial sectors.

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Table 1: Capability Building Blocks of Energy Efficicent Data Centres

	Level 1	Level 2	Level 3	Level 4	Level 5
Organizational Structure	No formal organizational structure	Resource efficiency is considered by IT and facilities, but there remains a siloed or disjointed approach.	Resource efficiency is inherent in policies. Management of the DC takes account of the interrelationship of IT and Facilities.	Holistic management approach with decisions balancing sustainability, resilience, and business needs.	A team led by a senior manager has responsibility for Resource Efficiency across the enterprise.
Policy	No formal resource efficiency policies in place	IT policies have limited consideration for decommissioning, consolidation, refresh, efficient storage allocation, and virtualization. Policy creation is essentially siloed.	Policy moves towards increased virtualization. Facilities have a defined improvement roadmap that targets sustainable operations. External best practices are systematically reviewed and internalised.	Policies reflect a harmonised, process-based approach. Resource efficiency is a criterion in terms of service offerings and purchases. There are CapEx funding programmes for upgrading infrastructure.	DC resource efficiency policy is a continuum from the enterprise level to the software code level and everything in between.
Manageability and Metering	No specific energy-related metrics or metering capability in place.	Basic information systems exist for energy data analysis and decision support. IT electrical load measures at the UPS level. PUE and DCiE are used.	The IT organization has a granular understanding of its IT electrical load. Facilities have an increased level of the support infrastructure metered.	IT has rack and server-level consumption data, together with environmental data such as temperature and humidity. Facilities infrastructure is completely metered from an energy standpoint.	IT can measure electrical load at the service level, matching consumption to useful work done. Facilities infrastructure and IT infrastructure is completely metered with appropriate, optimized automation.
IT Infrastructure & Services	Ad hoc	Defined IT landing procedures consider resource efficiency. There is auditing and decommissioning of unused equipment.	A comprehensive consolidation programme is in place. DC has moved some legacy services to virtualized environments.	Virtualization is the default practice for server and storage provisioning.	DC is almost exclusively virtualized. Dynamic service management allows for transferable workloads. IT moves towards a machine-readable SLA.
Internal Air & cooling	Ad hoc design and operation	IT Equipment is oriented in a cold aisle/hot aisle configuration.	Air inlet supply temperature is at the lower end of the ASHRAE recommendation. Row-based cooling maybe utilised.	Full air segregation is in place. There is cold aisle/hot aisle, chimney cabinets, or in-rack cooling. CRAC/CRAH have VFDs.	An optimal, floating, HUM setpoint is used. DC normal operational mode is 'free-cooling' economization.
Cooling Plant	Cooling is typically supplied based on resilience	Refrigeration infrastructure is appropriately sized or strategies are in place to align cooling capacity and demand.	COP is typically ~4-6. Pumps have VFDs. Partial wet side or airside economization is increasingly utilised – for ~50% of the year.	Refrigeration fans and pumps have VFDs. COP is typically ~6 or greater and normal operation is eco mode for ~75% of the year. Wet side eco / evaporation or direct free air cooling utilised.	Evaporative cooling (wet side economization), or, where possible, direct free air cooling is used. Direct touch cooling or new technologies maybe utilised.
Power Infrastructure	Power is typically supplied on a resilience basis only.	UPS is more effectively sized or strategies are employed to more appropriately align demand and capacity relative to existing IT load.	UPS is correctly sized. UPS is typically ~93% efficient or above at 50% load. There is an optimal number of PDUs.	UPS is correctly sized to DC load. Redundancy is appropriate for the criticality of the load. Rack PDUs are efficient with less than 3% loss. Power is delivered on a dynamic basis.	UPS is modular and efficient for the given DC. Appropriate non-critical applications are on mains-only power. Renewable energy sources are integrated, possibly utilizing direct current in major retro-fit scenarios.