A FRAMEWORK FOR ESTIMATING THE ENVIRONMENTAL COSTS OF THE TECHNOLOGICAL ARCHITECTURE
An Approach to Reducing the Organizational Impact on Environment

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Abstract: Green IT was developed from the growing concerns about the rise of the Information Systems energy cost and power consumption along with the need for an environmentally efficient image of the organization. This work addresses and links three main concerns: enterprise architecture modelling, need for energy cost cuts and energy efficiency of Information Technology. It describes a new method to estimate the IT architecture energy costs and CO_2 emissions, based on the technology layer of the enterprise architecture, and some solutions for solving or, at least, reducing the environmental impact of the latter.

1 INTRODUCTION

The use of Information Systems (IS) is growing (European Comission, 2008) (U.S. Environmental Protection Agency, 2006) and the consequence of this increase in the systems number and its working load (Gartner Research, 2007) is, among others, the rise of energy demands. This, combined with the need for operational cost cuts, the demand to comply with environmental standards (Energy Star, 2009) and regulations (United Nations, 1998) (United Nations, 2009) and the concern with implementing a marketing strategy to decrease the ecological footprint of the organization, emphasize the need for action (Global Action Plan, 2007) (Laplante, Nov/Dec 2008). These are the key areas at the heart of Green IT.

Our approach to Green IT is more than Information Technology (IT) infrastructure optimization, in a sense that it attempts to identify the existing problems in the infrastructure followed by a benchmark

This article aims at linking enterprise architectures, assets costs and technological infrastructure optimization to address the concerns mentioned before.

Therefore it reviews the latest developments in Green IT (2). The following two sections (3 and 4) describe the problems concerning Green IT and the approach chosen to solve them. That approach is demonstrated by using a model (section 5) and a simple example of its application (section 6). In section 7 this paper provides an overview about the latest research developments and its future prospects (9).

2 STATE OF THE ART

The next sections describe the latest developments in Green IT and a set of regulations and incentives to reduce the organization's eco-footprint.

2.1 Enterprise Architecture

There are three relevant enterprise architecture models to this work.

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The first one, Zachman Framework (Zachman, 1987), was published in 1987 and opened up an approach to organize and align the organizations IS with its business needs.

Today there is a sort of frameworks that allows us to represent the whole enterprise from business to technology concepts.

The most recent one is Archimate (Lankhorst, 2009). It defines a meta-model for business architecture modelling. It is divided in three organizational layers (business, applications and technology) and three organizational aspects (passive structure, active structure and behaviour).

Another similar tool is CEO Framework (FCEO) (Vasconcelos, Sousa, & Tribolet, 2007). This framework purpose is to model, on a non ambiguous way, the organizational targets, business processes and all of the resources used by the organization to reach the his goals.

2.2 IT Efficiency

The rise of energy consumption, the research of new technology and searching for new ways to reduce energy consumption and environmental impact created a new drive in the IT researching community.

The major concern in energy consumption of the IT infrastructure is the Data Centre (Deloitte Consulting, 2007). For that reason some optimizations and monitoring methods have been developed. Power usage controlling metrics (Belady, Rawson, Pfleuger, & Cader, 2008), optimization of chillers operation (Schmidt & Iyengar, 2009), room ventilation dynamics optimization (Hamann, et al., 2009) or the reutilization of the heat produced by servers (Brunschwiler, Smith, Ruetsche, & Michel, 2009) are some examples.

Other environmental efficiency improvements can be made using fresh technologies like Virtualization (Mann, 2009), Cloud-Computing (Vaquero, Rodero-Merino, Caceres, & Lindner, 2009) or storage consolidation plans (Sun StorEdge, 2005).

Another key factor is human behaviour. There are some daily actions taken that impact on energy consumption. Some of the solutions are simple as shut down computer screens while not in use or reutilize paper to print draft documents or print tests.

3 PRESENT PROBLEM

Considering the issues discussed in Sections 1 and 2, the problem addressed in this article is: “Could energy consumption numbers defined by the Technology Layer be used to estimate costs and identify environmental problems related to IT?”

Our approach to that problem is spread into three objective and targeted questions:

1. Could the data related to the energy consumption and environmental efficiency of artefacts used in Archimate Technology Layer (Lankhorst, 2009) be applied to determine the environmental cost of all the equipment owned by the organization?
2. Could the previous account be used to identify problems related to the Technology Architecture layer?
3. Completed the problem identification stage, are there any solutions to improve environmental efficiency that could be implemented?

Out of the work scope are subjects such as automatic architecture identification and the use of other enterprise architecture layers above technology (such as business, application or information architecture layers).

4 THE APPROACH PROPOSED

As previously mentioned in Section 3, the suggested approach to the problem follows three steps. The first one is to find out what Archimate Technology Layer artefacts (Lankhorst, 2009) extensions are needed to keep track of equipments environmental cost. Those artefacts are extended with fields representing the equipments specifications required to do the cost estimation.

The second step is related to measure the IT environmental cost. To do this a model was designed to estimate power consumption. The model related to servers and PC’s is based in real-time load measurements in order to estimate the IT system power usage on given moment.

The last step for solving the problem involves the suggestion of a set of ideas to reduce the IT environmental footprint. They are related to the IT optimizations presented on sub section 2.2.

5 POWER USAGE ESTIMATION

Using measurements made by SPEC (Standard

Performance Evaluation Corporation 2010) a first version of a server energy consumption estimation model has been created.

Using data of a set of one hundred and thirty two measured servers, provided by SPEC, a method has been developed for energy consumption estimation based on the server load.

This method assumes that real power consumption of the server for *full* and *idle load* stages is previously known. Based on those two stages figures and using a linear analysis represented on Equation 1, power consumption can be estimated in real time.

$$P_{est}(l) = P_{idle} + \left((P_{MaxLoad} - P_{idle}) \times l\right) \quad (1)$$

Tests run using data provided by the SPEC measurements showed that this method has an average error of 3.25%. Also there's a data correlation of 0.99354 between system load and the real energy consumption values, so this is a good approach.

6 METHOD APPLICATION EXAMPLE

Suppose there are two servers X and Y connected by a network. The target of this analysis is to estimate the CO_2 emissions that each one of them produces. Consider that the load of each server is 20%.

To represent this IT architecture using Archimate and those environmental concerns, the artefact *Device* has to be extended with the following fields:

- **Load** – Shows the system's load percentage;
- **Energy Consumption** – Model estimation of device energy consumption;
- **CO2Emissions** – Model calculation of device energy consumption;
- **Idle Power** – Power usage of the system in the idle state;
- **Maximum Load Power** – Power usage of the system in full load state.

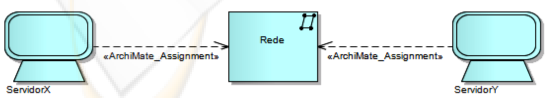

Figure 1: Archimate representation of Servers X and Y.

The graphical representation of the architecture using Archimate model is shown in Figure 1.

The figures of power usage on full (*MaxLoadPower* field) and idle load states (*IdlePower* field) are previously known. Each server test sample has been randomly selected from the SPEC measurements to represent servers X (SPEC_1, 2008) and Y (SPEC_2, 2008). In Table 1 energy usage values for servers X and Y are shown for idle and full load stages and real energy usage is shown at 20% system load (Real Power Usage column) for later comparison. Using the approach based on a linear growth of power usage related to the system load on each moment, the Equation 1 can be used to estimate the power usage for servers X and Y.

Having the estimated figures for energy consumption it is possible to calculate the CO_2 emissions produced by servers. For that purpose a Portuguese government regulation (Diário da República, 2008) establishes the conversion factor.

The results shown on Table 2 are the server power usage estimation and its related emissions.

Comparing the real power usage figures shown in Table 1 with the estimated figures for Servers X and Y the results are drifted 7W (6.2%) and 2W (1.1%), respectively.

7 ON GOING RESEARCH

This section presents the latest improvements in the power consumption estimation model.

7.1 Server Power Estimation Model

The suggested model shows some inaccuracy and functioning limitations.

The tests run with data provided by SPEC study have shown a higher error of 6% between real and estimated values at the 20% CPU load.

Table 1: Servers Consumptions.

State / Server	*Idle* (W)	Full Load (W)	Real Power Usage (W)
Server X	89.40	173.00	113.00
Server Y	155.00	269.00	176.00

Table 2: Estimated Environmental Costs.

Cost / Server	Estimated Power (W)	Emissions ($kgCO_2eq$)
Server X	106.12	0.0499
Server Y	177.80	0.0836

To improve it the model has been transformed from a linear growth between idle and full load stages to a model split into two sections: idle to 20% CPU load stage; 20% CPU load to full load stage. Based on the same principles used on the original model the power usage at 20% CPU load is computed but increased in 10%. After that the original method is applied for both sections using the new value of power usage at 20% load stage. Then a transformation occurs in the graphical representation showing two lines with different slopes.

This approach achieves a reduction of 1% on the model average error.

To mitigate a final limitation, an upgraded version of the model is being developed to be more practical on real situations when data related to both idle and full stages are not available.

The data resulting from SPEC study has been modelled into multiple dimensions which consider server specifications like the number of CPU chips, cores per CPU or memory slots engaged. Using this approach the aim is to find a typical value of power usage for the idle and full power stages with the combination of these multiple dimensions.

7.2 Printers Application

At present, the implementation of a model to estimate the environmental footprint of printers in the technology architecture is about to be completed.

There are two goals to be achieved with this model: the first one is to prove that the principles used for server's power usage accounting could be implemented in other technological equipments; and the second one that is possible to use this efficiency accounting to rate equipments and find out problems of environmental efficiency on the technological layer.

To achieve the first step, for each printing device the model uses values related to the average time needed to print one page, number (or average number) of pages printed on a given time frame and the manufacturer declared power usage for printing. Also, for each device, the manufacturer power usage definition for idle and, if available, "power saving" mode, are considered. Using this data the model can keep the account of the average energy consumption on a given time frame.

The second step uses a framework that is based on the ratio between the energy used and the number of pages printed during a given month. With this ratio calculated for each printer and using the office layout and equipments distribution it is possible to graphically check if there are areas in the IT infrastructure that have energy usage inefficiency. This generic method is also possible to apply to servers, using a relevant ratio, like PUE (Rawson, Pfleuger, & Cader, 2008), to calculate the environmental efficiency of the equipments.

This approach is being applied in Deloitte's office in Lisbon. It is expected that the model will help to determine existing problems on printer's layout and launch a staff awareness campaign on energy consumption and paper use reduction.

8 CONCLUSIONS

This article gives a new approach to the problem of environmental costs. This relates the enterprise architectures with cost accounting to estimate the environmental costs of IT operation.

This new approach holds a great potential to address the environmental concerns of enterprise organizations. Also, it's a work with good prospective of future applications due to its possible extension to the upper layers of the enterprise architectures and the relation with the environmental performance, both areas with so many developments today.

9 FUTURE WORK

This article traces a plan for a future work on Green IT developments in energy consumption. As it follows:

- A test on real environment is planned to compare the results obtained using the model to estimate the energy consumption against the real consumption figures measured on the IT systems considered. Although real energy consumption figures are being used in the theoretical model tests, this test in real environment will allow us to compare the model's accuracy in a real time estimation and under real work load;
- This work only considers the technological layer of the enterprise architecture. The extension of this approach through all the others layers is being considered. Therefore it will be possible to carry on with CO_2 emissions quantification of the organization's products, service delivery and processes. Going through all layers enables a wider perception and a strategic awareness of the environmental impact of the organization's energy consumption.

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