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Does Green IT Matter? Analysis of the Relationship between Green IT and Grid Technology from a Resource-Based View Perspective

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DOES GREEN IT MATTER? ANALYSIS OF THE RELATIONSHIP BETWEEN GREEN IT AND GRID TECHNOLOGY FROM A RESOURCE-BASED VIEW PERSPECTIVE

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Abstract

Due to the significant increase in IT-related power consumption and the resulting higher CO_2 emissions, Green IT has gained considerable attention in industry and society in recent years. Green IT as an engineering paradigm defines the multi-faceted, global effort to reduce power consumption and the promotion of environmental sustainability. This encompasses the manufacturing and purchasing of energy efficient IT equipment, the efficient operation and utilization of hardware devices, as well as its proper disposal. This article depicts the results of an analytical approach to find parallels between Green IT requirements and the economical and ecological benefits of Grid technology implementation. Therefore, the main objective of this article is to illustrate how Grid technology materializes the Green IT paradigm and its inherent benefits. In addition, by applying the Resource-Based View to Green IT, the article illustrates that the assimilation of a Green Grid infrastructure leads to increased competitiveness of enterprises in the market.

Keywords: Green IT, Grid Computing, Virtualization, Resource-Based View.

1 INTRODUCTION

With the growing acceptance that CO_2 emissions are a major cause for global warming and the changes of weather patterns, enterprises, governments, and society at large are beginning to consider environmental issues in the process of technology adoption leading to an increasing application of environmentally sound practices (Murugesan 2007). This includes the reduction of electric power consumption of IT hardware which uses up significant amounts of electricity, placing a heavy burden on the power grids (Murugesan 2008). According to a report provided by the Department of Energy (2007), data centers were estimated to have used 1.5 percent of all electricity in the United States in 2006, and their power demand is projected to grow 12 percent per year through 2011. Furthermore, many data centers are responsible for 30 to 40 percent of the energy consumption of an enterprise (O'Connor 2008). Therefore, a major objective of the IT industry is to reduce the power consumption and the environmental impact of IT to facilitate the emergence of a more sustainable environment.

Another major source of environmental problems is the production and disposal of IT, wherefore the green wave is sweeping the IT industry and the business domain. The trend of "greening" IT products, applications, services, and practices will continue since Green IT (also known as Green Computing) provides opportunities to reduce the accumulation of greenhouse gases in the atmosphere by reducing global CO_2 emissions. The current Green IT initiatives are especially reinforced by social and political pressure, governmental regulation, rising cost of waste disposal, corporate images, and public perception (Unhelkar and Dickens 2008, Kurp 2008).

Since little research has been conducted on Green IT and due to the several parallels between Green IT requirements and the characteristics of Grid technology, this article depicts the results of an analytical approach and outlines to what extent Grid technology can be used to implement the concepts of Green IT in order to leverage the inherent ecological and economical benefits. In addition, by applying the Resource-Based View to Green IT, the article illustrates that the assimilation of a Green Grid infrastructure leads to increased competitiveness of an enterprise. Due to the conceptual research approach, the guidelines proposed by Hirschheim (2008) have been considered to improve the rigor of the conducted research and to make a significant contribution to the knowledge of the relationship between Green IT, Grid technology, and competitive advantage of a firm.

The remainder of this article is organized as follows. First, a brief overview of Green IT and its concepts is provided in section 2. Section 3 emphasizes the need for Green IT infrastructures in order to reduce the power consumption in data centers and provides an introduction into Grid technology. Section 4 shows that the assimilation of Grid technology in the industry can be an effective implementation of Green IT concepts leading to increased competitiveness of enterprises, which will be illustrated in section 5. The article concludes with a summary of the key findings and an outlook to further research questions.

2 GREEN IT

Today, IT organisations are facing the dual challenge of providing more computing capabilities to meet dynamically changing and expanding business needs and thereby delivering such capabilities cost effectively as well as power and cooling efficient (Scaramella and Healey 2007). Due to this, IT manufacturers and vendors increasingly invest in Green IT initiatives and produce or use ecologically friendly and energy efficient IT solutions.

According to Murugesan (2008, pp. 25-26), Green IT is defined as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems (monitors, printers, storage devices, etc.) efficiently and effectively with minimal or no impact on the environment". This definition illustrates that the term "Green IT" is multifaceted and covers manifold aspects of environmentally sound IT solutions and practices. Since IT is a major source of environmental problems at each stage – from its production, throughout its use, and into its disposal –

Green IT strives to achieve economic viability and improved system performance and use while regarding social and ethical responsibilities (Murugesan 2008).

During the last few years, the IT industry has identified Green IT as a way to handle environmental issues of IT and to create new market opportunities. Enterprises with the technology and vision to provide products and services that address environmental issues are likely to achieve a sustained competitive advantage (Ryan 2008) by reducing energy costs. In addition, IT investors and consumers are beginning to look at the carbon footprint of an IT company and its products whereby a carbon footprint is a measure of the total set of greenhouse gas emissions caused directly and indirectly by an individual, an organization, an operation or a product (Kurp 2008). As a result, IT companies increasingly advertise their environmental credentials and disclose their carbon emissions in order to be recognized as being an environmentally responsible company. Due to this, the IT industry sees environmentally sustainable IT as the key to future success as evidenced by recent industry research reports provided by analyst firms like Gartner and IDC that have identified Green IT as one of the major trends of the IT industry for 2009 (Gartner 2008, IDC 2008). However, the building of a "greener" environment requires modifying or abolishing old and familiar ways of doing things and discovering new processes and methods.

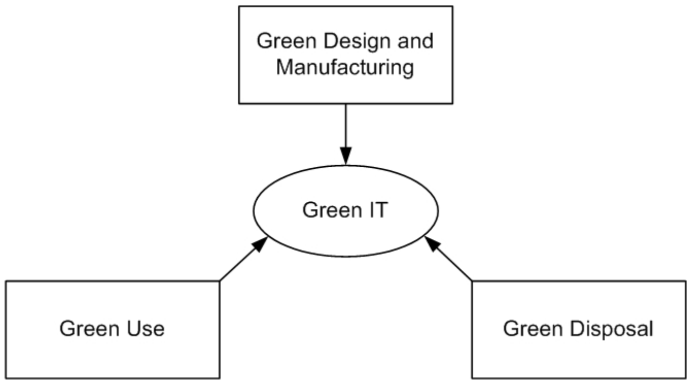

Figure 1. Different dimensions of Green IT

Figure 1, which is derived from Murugesan (2008), depicts a model that comprehensively addresses the environmental impacts of IT. The model illustrates three different dimensions of Green IT that are explained in further detail in the following sections.

2.1 Green Design and Manufacturing of IT Systems

Green IT design aims at designing environmentally sound and energy efficient IT equipment to reduce the environmental impact of IT. This can be achieved by adopting new techniques and materials that are both environment friendly and economically advantageous. Currently, the IT industry is investing significant resources in green initiatives such as developing energy efficient servers, data center cooling solutions, and new materials and design options.

Prominent examples for efficient Green IT design are the move from single-core to multi-core CPUs that consume less power (Petrini et al. 2007) and the move from 65 to 45 nanometer chips that have an increased energy efficiency and an improved performance per watt ratio (Allarey et al. 2008). Another example is the design of thin clients. With thin client computing, applications do not run locally on the user's device but on a server in the network. Since all functionality and hardware that is not related to user's input and output is removed from the thin clients, and complex calculations are performed on servers, thin clients consume less energy than typical desktop computers (Simoens et al. 2007).

Green IT manufacturing describes the increasing effort of IT manufacturers to improve their production processes from a life cycle point of view so that they produce IT equipment with, e.g., energy efficient processors, new power management features, and recyclable materials (Kurp 2008).

Due to the rising power consumption of data centers, power-aware computing has gained considerable attention in the high-performance computing (HPC) community over the last few years. As a result, low-power, high-performance clusters, such as Green Destiny (Warren et al. 2002), have been developed to stem the ever increasing demand for energy. Green Destiny was the first HPC system that was built with energy efficiency as its guiding principle and focused more on efficiency, reliability, and availability than on just pure speed (Feng et al. 2008).

2.2 Green Use of IT Systems

Due to the fast growing number of Web applications as well as compute and data-intensive business applications, enterprises are continuously expanding the capacity of their IT resources and their data centers in particular consuming significant amounts of electricity and generate tremendous heat. In order to ensure the stability of the IT resources, effective cooling systems are required that further add to the total power consumption and cost for the enterprise. According to a report provided by Scaramella and Healey (2007), for every dollar in server spending today, companies spend $.50 on power and cooling, and it is expected to rise to $.70 by 2010. Furthermore, the report predicts that the expense to power and cool servers will grow four times faster than the growth rate for new server spending by 2012. Besides the energy cost, the availability of electrical power is becoming a critical issue for many enterprises whose data center capacity has expanded steadily (Murugesan 2007).

Therefore, the green use of IT systems aims at decreasing energy cost and minimizing the greenhouse gas emissions by increasing the efficiency and reducing the energy consumption of IT resources.

One way to reduce energy consumption is to invest in energy management software that shuts down IT equipment completely or at least powers it down to an energy saving standby mode if it is not being used (Meisner et al. 2009). The power consumption in data centers can be reduced by migrating applications from mainframe computers to servers since mainframe computers generate significant amounts of heat, and thus require special air-conditioning systems to keep temperatures within manufacturer-specified ranges (Murugesan 2008).

IT efficiency can be improved by using energy efficient IT equipment, improved airflow management systems that reduce cooling requirements, and especially virtualization technology. Virtualization technology is a major strategy to reduce the energy consumption of data centers. In typical data centers, average utilization is only 20-30% (Bohrer et al. 2002). Server virtualization aims at splitting hardware resources into several smaller virtual machines, enabling more than one virtual machine on a single hardware, thereby increasing multitasking capability, increasing utilization of servers, and improving energy efficiency. Enterprises can thus shut down numerous servers and thereby reduce power usage significantly leading to a significant cost reduction.

In order to facilitate the reduction of power consumption and improvements in energy efficiency in data centers, leading IT enterprises formed the non-profit group “The Green Grid” that seeks to define and propagate best energy efficient practices in data center design, construction, and operation and defines Green IT metrics and technology standards (Green Grid 2009)

2.3 Green Disposal of IT Systems

It is not uncommon that companies replace their older IT equipment with new, more energy efficient ones in an effort to become more environmentally friendly (Kurp 2008). However, this practice is not always the most environmentally sound solution due to the need to dispose the old IT equipment. Due to this, Murugesan (2007) calls for green disposal of IT systems and thereby requests the industry to reuse, refurbish, or to recycle old IT equipment in environmentally sound ways.

The *reuse* of IT hardware aims at extending the life cycle of IT hardware which can be achieved by using hardware for a longer period of time, by giving it to other departments or users who need it, or by using functional components from retired products. These actions should lead to a reduced environmental footprint caused by IT hardware manufacturing and disposal.

The goal of *refurbishing* IT systems is to upgrade computers and servers to meet new requirements. This can be done by reconditioning and replacing functional components rather than buying new IT hardware.

If IT hardware cannot be reused or refurbished it has to be *recycled* or at least properly disposed of in an environmentally friendly way. Electronic waste, or e-waste, mostly ends up in landfills and therefore is an emerging problem, given the volumes of e-waste being generated and the content of toxic substances in them. This fast growing e-waste stream is accelerating because the global market for computers is far from saturation and the average lifespan of IT hardware is decreasing rapidly (Widmer et al. 2005).

3 NEED FOR GREEN IT INFRASTRUCTURE

Due to the increasing competition in the industry and the current market dynamics, enterprises are forced to adopt HPC technology in order to stay competitive. According to a study by Joseph et al. (2004), 97 percent of the U.S. businesses surveyed could not exist, or could not compete effectively, without the use of HPC technology. But due to the high cost of power consumption and cooling, enterprises are facing the dual challenge of adopting more HPC technology to meet dynamically changing business needs and thereby delivering such capabilities cost effectively as well as power efficient (Scaramella and Healey 2007). As already outlined, Green IT can support enterprises to use IT equipment in an environmentally friendly way by reducing the power consumption of IT hardware.

To “go green”, enterprises can take straightforward actions like, e.g., implementing the Energy Star guidelines for energy efficiency in data centers or refurbishing and upgrading old IT equipment instead of buying new IT hardware. But Williams and Curtis (2008) argue that these are only point solutions and request that a comprehensive plan for achieving Green IT does require an architectural approach.

Biros et al. (2008) and Olson (2008) state that Green IT efforts cannot be undertaken overnight and take longer to break-even since many enterprises cannot afford to replace their existing systems with newer, Green IT solutions immediately. Grid technologies provide enterprises with the opportunity to build up an own Green IT solution by connecting existing IT hardware into a Grid without needing to invest in new hardware. Furthermore, since one of the major benefits of Grid technology is the exploitation of under-utilized or unused IT resources, Grid technology seems to be a promising way to provide enterprises with high computational power while being energy efficient. Before this article will present to what extend Grid technology can be used to implement the concepts and requirements of Green IT, a brief introduction to Grid computing is given.

Following the publication of the seminal work by Foster and Kesselman (1999), interest in Grid computing has grown rapidly, attracting considerable attention from both academia and industry. This interest has been facilitated by the availability of powerful computers and high-speed networks as low-cost commodity components and ultimately by the growth of the Internet that made it very easy to discover and manage computing resources distributed across a Grid.

Meanwhile, Grid computing has evolved into a well-understood technology that provides users and applications with immediate access to a large pool of IT resources, such as supercomputers, server clusters, servers, desktop computers, storage systems, and databases that can then be used as a unified resource. According to the widely accepted definition provided by Foster (2002), a Grid is defined as a system that coordinates IT resources that are not subject to centralized control, uses standards, open protocols and interfaces, and delivers non-trivial Qualities of Service (QoS). Regardless of their operating characteristics, Grid technology enables heterogeneous and geographically dispersed IT resources to be virtually shared and accessed across an industry, enterprise, or workgroup. Although much effort and expertise is associated with building up a Grid infrastructure, several tools (e.g., the Grid Development Toolkit for Eclipse) support non-Grid experts in developing distributed Grid applications for existing Grid infrastructures (Friese et al. 2006).

Grid technology provides several benefits, including seamless computing power achieved by exploiting under-utilized or unused resources, resource allocation and load balancing based on Service Level Agreements (SLAs) to meet QoS requirements, and a more reliable, resilient, and scalable infrastructure with autonomic management capabilities and on-demand aggregation of resources from multiple sites to meet unforeseen demand. A thorough literature overview of the benefits of Grid technology and suitable application domains for Grid architectures in the industry domain is provided in a recent article by Vykoukal et al. (2009).

4 IMPLEMENTATION OF GREEN IT CONCEPTS

As already illustrated in section 2, the environmental impact of IT can be analyzed along three different dimensions: IT design and manufacturing, IT use, and IT disposal. As presented in Figure 2, Grid technology can be used to address these three dimensions of Green IT, which will be illustrated in further detail in the following sections.

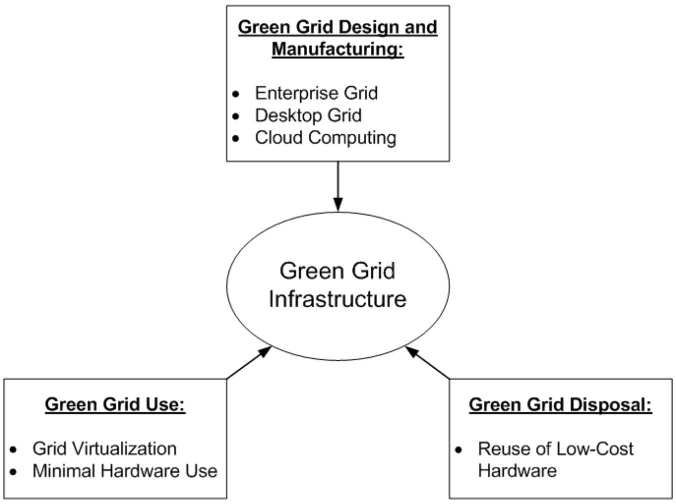

Figure 2. Implementation of Green Grid Infrastructure

4.1 Green Design and Manufacturing of a Grid

The migration to a Grid infrastructure can be seen as Green Design of IT systems since enterprises can chose between different types of Grid, such as an Enterprise Grid or a Desktop Grid that can be used to reduce power consumption of IT resources, as will be illustrated in the following. In addition, an enterprise can purchase Grid resources from external services providers on a pay-per-use basis, which is called Cloud computing.

- *Enterprise Grid:*
  Enterprises increasingly need high computational power to meet dynamically changing and expanding business needs which can be achieved by exploiting Grid resources. In an Enterprise Grid, all major computing and storage resources of an enterprise (including IT resources of data centers) are consolidated and shared across the departments of the entire enterprise leading to an improved resource utilization and thus significant cost savings (Strong 2005). The services and applications that are provided and obtained through an Enterprise Grid may range from the traditional commercial enterprise applications to newer, distributed applications or services. The benefits of an Enterprise Grid in regard to Green IT are higher resource utilization and significant cost savings for businesses, since they do not need to purchase expensive, high-end IT equipment that in most cases consume large amounts of power for the purpose of running their high performance applications. However, the environmental impact of a Grid could further be decreased by investing in power efficient hardware components that are integrated into the Grid.

- *Desktop Grid:*
  Another type of Grid is the Desktop Grid that can easily be integrated into an enterprise-wide Enterprise Grid. The vision of a Desktop Grid is to harness the collective power of existing underutilized computational resources of desktop computers found in offices within an enterprise or organization (Marowka 2007). Unlike a dedicated computer cluster, the resources of desktop computers cannot be accessed exclusively but when they are not fully utilized by their direct interactive users and have spare capacity. Since most of the today's desktop computers or laptops contain multiple CPUs, "cycle stealing" is a common practice in Desktop Grids while maintaining low obtrusiveness to the desktop computers' owners. Since some desktop computers are not switched off at night, during weekends, and on holidays, the resources can exclusively be utilized. Nevertheless, it is more environmentally sound to switch off computers when they are not in use.

- *Cloud Computing:*
  Besides the development and implementation of an own Grid infrastructure, Grid technology allows enterprises to purchase IT resources (mostly commonly computing or storage resources) directly from external services providers over the Internet on a use-on-demand, pay-per-use basis. In order to offer a large pool of IT resources to customers, external services providers interconnect a large number of IT resources into a Grid and virtualize the resulting Grid infrastructure. Since the virtualized Grid is a fully scalable and abstracted infrastructure that can host a large number of applications, the Grid may also be called "the Cloud". The main characteristic of Cloud computing is that the use of Grid resources is billed by consumption.

  Currently, there are only a few external providers that commercially offer Grid resources on a use-on-demand, pay-per-use basis, such as Sun Microsystems offering on-demand computing resources (Sun 2009), Amazon offering on-demand storage and computing resources in form of virtual machines accessible over the Internet (Amazon 2009), or Google offering a Platform-as-a-Service (Google 2009). This allows enterprises to purchase computing power, storage or a complete virtualized Grid infrastructure as needed without the long-term life-cycle costs associated with capital acquisition, systems management, and operational expense, which leads to a faster IT response to changing business needs. Especially for small companies without the financial opportunity to invest in their own Grid infrastructure, the on-demand use of Grid resources can open up new business models due to the lower total cost of ownership.

  Since third-party Grid resource providers increasingly expand their network of massive data centers with hundreds of thousands of servers, petabytes of data, and hundreds of megawatts of power, they tend to be more power consumption conscious than enterprises that utilize less IT resources. Due to the exploitation of economies of scale in transport, provisioning, powering, cooling, and recycling of IT equipment, Grid services providers are able to invest in energy efficient practices and technologies. Due to this, future Grid infrastructures are likely to be far more power efficient than today. In addition, Grid providers increasingly adopt energy efficient servers, utilize virtualization technology to maximize the utilization hardware, and build new data centers in locations with moderate climates (e.g., Iceland or Siberia). By using cold outside air for cooling of the data center, there is lesser need for power to operate mechanical chillers to produce cool air, thus reducing overall energy consumption. For example, Microsoft, that is about to offer Grid resources on-demand to customers, has built a large data center in Ireland which is, due to the moderate climate in Ireland, air cooled and therefore 50% more energy efficient than other comparably sized data centers (Kurp 2008). As a result, enterprises that are not able to invest in own energy efficient and power effective IT equipment have the opportunity to purchase IT resources from external services providers that have already invested in Green IT initiatives and therefore offer power and cooling efficient Grid resources leading to reduced carbon emissions.

4.2 Green Use of a Grid

As will be illustrated in the following, the environmentally sound use of IT resources can be implemented by virtualizing a Grid infrastructure and by developing a globally distributed Grid to minimize the number of servers, storage, and other IT equipment that consume significant power.

- *Grid Virtualization:*
  Instead of needing to buy more powerful and expensive servers or storage devices, Grid technology provides enterprises with the opportunity to integrate commodity servers and network storage into a Grid infrastructure leading to increased computing power and storage capacity. In addition, if Grid resources are underutilized, resources can be removed from the Grid without affecting the resilience and stability of the Grid. These characteristics lead to an increased flexibility and scalability of the entire Grid infrastructure and higher levels of resource utilization, which can be further enhanced by the application of virtualization technology (Foster and Kesselman 1999).

  In contrast to server virtualization that aims at splitting hardware into smaller virtual machines, Grid virtualization is used to aggregate a large pool of hardware resources and thus hides the complexity of the aggregated Grid resources from the user. The user accesses the aggregated hardware (e.g., large number of CPUs, large amount of storage) as a single virtual organization and benefits from significant processing power and large storage capacity.

  Grid virtualization technology can be combined with autonomic resource and data management solutions to automatically handle fluctuating workloads and peak demands by adding resources to the Grid infrastructure or by removing them from the Grid. Furthermore, where feasible, applications can automatically be parallelized and distributed across multiple Grid resources to decrease the processing time of applications and thus to meet the expanding need for high processing capacity. Due to this, Grid infrastructure technology and virtualization technology can be used to enable effective management of the shared resources leading to a dynamic and powerful IT infrastructure. Further, computational workloads can be delegated to more energy efficient resources such that less energy efficient resources can be powered down (Patel et al. 2003). As a consequence, effective Grid virtualization leads to minimal power consumption since the number of running hardware components of a Grid can dynamically and automatically be scaled to fit the fluctuating demand and maximize the resource utilization.

  Simulation results provided by Beck et al. (2008) indicate that the virtualization of Grid resources in combination with a price-based allocation of resources can produce a cost reduction of about 40 % compared to individual and dedicated servers. Further, Opitz et al. (2008) attempted to analyze the costs associated with Grid technology by identifying different cost factors (hardware, business premises including electricity, software, personnel, and data communication). They concluded that the costs of Grids are between $0.20 and $0.94 per CPU and hour whereas the costs of a traditional computing center range from $2 to $12 per CPU and hour, which emphasizes the significant cost saving potential of Grid technology.

- *Minimal Hardware Use:*
  In order to further decrease the number of running hardware components in a large enterprise, Grid technology allows for the development and implementation of a globally distributed Grid infrastructure that may interconnect data centers of a multi-national enterprise located around the world across multiple time zones. By sharing idle resources of such a Global Grid among geographically dispersed sites or branches, enterprises can take advantage of the different time zones and use idle resources of different time zones across the world in peak hours (Strong 2005). Due to this, enterprises can further reduce expenses for new resources and reduce power consumption while providing significant computational and storage capacity to the branches.

4.3 Green Disposal of a Grid

Grid technology allows for the integration of heterogeneous IT resources into a Grid. Therefore, even less-powerful servers and desktop computers that are designated to be disposed of can be reused in a Grid infrastructure. As a consequence, an enterprise does not need to invest in more powerful and expensive servers to meet the ever increasing business demand for powerful IT infrastructures (Vykoukal et al. 2009).

5 RESOURCE-BASED VIEW OF GREEN IT

The conclusion of the previous section is that Grid technology allows for the implementation of a Green infrastructure that provides large computing and storage capacity while consuming minimal electric power. Due to this, the assimilation of Grid technology in the industry is shown to be an effective implementation of Green IT leading to competitive advantage of enterprises, which will be illustrated in the following by applying the Resource-Based View to Green IT.

The Resource-Based View suggests that a firm exhibits different resources, a subset of which helps attaining a competitive advantage whereas a further subset enables to sustain the competitive advantage eventually leading to increased financial firm performance (Barney 1991). Consistent with the extant literature (e.g., Sanchez et al. 1996), basically two different kinds of resources can be distinguished: assets and capabilities.

Assets are defined as tangible or intangible resources the firm can use in its processes for creating, producing, and/or offering its products to a market. Consistent with Ross et al. (1996), one can distinguish between human, technology, and relationship assets. In the context of Green IT, a technological asset of a firm can be a high-capacity Grid infrastructure with minimal power consumption.

Capabilities reflect the repeatable patterns of action in the use of assets. The capability construct is conceptualized by inside-out, outside-in and spanning capabilities (Day 1994). *Inside-out* capabilities exhibit a strong internal focus and are deployed from inside the firm in response to market requirements and opportunities (e.g., technology development, cost controls). In contrast, *outside-in* capabilities are externally oriented and encompass the anticipation of market requirements, the building and management of durable external relationships and the awareness and understanding of competitors. Finally, *spanning* capabilities are employed to integrate a firm's inside-out and outside-in capabilities in reliable business partnerships.

With regard to the capability building process, Green IT contributes to the creation of inside-out, outside-in, and spanning capabilities. As presented in the previous section, the total cost of ownership can effectively be decreased by the application of Green IT compliant technologies (i.e., Grid technology), thereby enhancing the firm's inside-out capability to operate IT infrastructure technology in a cost effective way (Ross et al. 1996, Feeny and Willcocks 1998). With the increasing social pressure and customer demand for Green IT initiatives and solutions, enterprises are forced to enhance their outside-in capabilities by the application of environmentally sound practices (e.g., the development and implementation of a Grid infrastructure), which leads to a positive influence on the public perception of the enterprise and to stronger ties with customers and business partners. As long as only a small number of competitors adopt Green IT solutions for their businesses, enterprises can achieve a competitive advantage by being an early adopter of ecologically friendly and energy efficient IT solutions (e.g., Grid infrastructures). Lastly, the spanning capability of an enterprise can be enhanced by the development of a comprehensive, enterprise-wide Green strategy as requested by Williams and Curtis (2008) to realize further cost reduction potential and to further enhance the public perception of the enterprise and its relationship with business partners.

After a competitive advantage has initially been achieved, it has to be sustained in order to enhance long-term financial firm performance. Therefore, the resources of a firm have to be valuable, sustainable, rare, and inimitable (Barney 1991). A Grid as an implementation of Green IT is very *valuable* and *sustainable* since it provides enterprises with a cost-effective, powerful, and resilient infrastructure that can be utilized for a long period of time. In addition, since Grid technology has not yet been adopted by a large number of enterprises, Grids are still relatively *rare* in the industry domain and can help enterprises to maintain their competitive advantage. However, the increasing number of IT services providers offering easy-to-use Grid services makes it very easy for competitors to utilize Grid resources on-demand, wherefore it can be expected that Grid technology will not continue to be rare in near future. Due to this, enterprises need to be continuously innovative to achieve *sustained* competitive advantage. Lastly, a Grid can be seen as an *imitable* resource since every enterprise is able to build up an own Grid infrastructure by interconnecting the existing hardware resources or to purchase Grid resources of external services providers.

As a consequence of this discussion, the adoption of Grid technology as implementation of Green IT does not necessarily lead to sustained competitive advantage of an enterprise but Grid technology can at least help enterprises to stay competitive in a fast changing business environment.

6 CONCLUSION AND OUTLOOK

The article emphasizes the importance of environmentally sound practices especially in the IT industry due to the significant power consumption of IT hardware that consumes significant amounts of electricity, placing a heavy burden on the power grids and on the environment.

Due to several parallels between Green IT requirements and the characteristics and benefits of Grid technology, this article presents the results of an analytical approach to analyze and evaluate the extent to which an enterprise can reduce the power consumption of its IT equipment by developing and implementing a Grid infrastructure. Many enterprises cannot afford to immediately replace their existing IT systems with newer, environmentally friendly IT solutions, wherefore Grid technology provides enterprises with the opportunity to build up an own Green IT solution relatively fast by interconnecting existing computing and storage capacity into a Grid. Another option for enterprises is to purchase Grid resources on-demand from external services providers that have already launched Green IT initiatives.

By virtualizing the Grid infrastructure, under-utilized or unused IT resources can be exploited by a large number of users or applications leading to an increased processing power and increased storage capacity. In order to minimize the power consumption of hardware resources, Grid virtualization technology can be combined with autonomic resource and data management tools that transform the Grid into a "breathing" IT infrastructure with constantly high resource utilization and reduced power consumption. Therefore, for an enterprise, the development and implementation of Global Grid is favorable and beneficial compared to building several closed Grids in single countries. Due to this, the assimilation of Grid technology in the industry is shown to be an effective implementation of Green IT concepts leading to increased competitiveness of enterprises in the market.

The results of this conceptual article are intended to provide a valuable contribution to theory and practice. Since little research has been conducted on Green IT so far, this article is a first approach to theoretically analyze the relationship between Green IT and Grid technology. Furthermore, the article applies the Resource-Based View with regard to a more nuanced view on ecologically friendly use of IT resources. Finally, the impact of Grid technology on business value generation is depicted by the application of the Resource-Based View. The next step will be to empirically measure the economical and ecological impact of Green IT and Green Grid initiatives and its drivers.

Besides the theoretical contribution, the results of the article are moreover of interest for enterprises that are planning to reduce power consumption of their IT systems while providing significant computational and storage capacity to its departments. Grid technology is shown to be suitable for the implementation of Green IT concepts leading to increased competitiveness of the assimilating enterprise.

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