Research Report

Analysis of the Relationship between Green IT and Grid Technology

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.

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Introduction

During the last few years, the awareness that CO_2 emissions are a major cause for global warming and the changes of weather patterns has grown steadily. Therefore, enterprises, governments, and society at large are beginning to consider environmental issues in the process of technology adoption. This includes the reduction of electric power consumption of IT hardware which needs significant amounts of electricity and places a heavy burden on the power grids. According to a report provided by the Department of Energy, data centers were estimated to have used 1.5% of all electricity in the United States in 2006, and their power demand is projected to grow 12% per year through 2011. Furthermore, many data centers are responsible for 30 to 40% of the energy consumption of an enterprise. Therefore, a major objective of the IT industry and also the financial services industry with its high computational demands 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. This triggered a green wave that is sweeping the IT industry and the business domain. The trend of "greening" IT products, applications, services, and practices will likely continue since Green IT 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 costs of waste disposal, corporate images, and public perception.

Since little research has been conducted on Green IT, this article depicts the results of an analytical approach to find parallels between Green IT requirements and the characteristics of Grid technology. In doing so, the article outlines to what extent Grid technology can be facilitated to implement the concepts of Green IT and to leverage the inherent ecological and economical benefits.

Green IT

According to Murugesan (2008), 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 aims to cover manifold aspects of environmentally sound IT solutions and practices. Since IT is a major source of environmental problems at each stage of its lifecycle – from its production, throughout its use, and into its disposal – Green IT strives to achieve both economic viability and improved system performance while regarding social and ethical responsibilities.

Figure 1, which is derived from Murugesan (2008), depicts a model that comprehensively addresses the environmental impacts of IT and illustrates three different dimensions of Green IT.

"Green IT design" aims at designing environmentally sound and energy efficient IT equipment to reduce the environmental impact of IT. Prominent examples are the move from single-core to multi-core CPUs and the move from 65 to 45 nanometer chips that have increased energy efficiency and improved performance per watt ratios.

"Green IT use" aims at decreasing energy costs and minimizing the greenhouse gas emissions by increasing the efficiency and reducing the energy consumption of IT resources. IT efficiency can be improved, e.g., by using virtualization technology as a major strategy to reduce the energy consumption of data centers. In typical data centers, average utilization is only 20-30%. Server virtual-

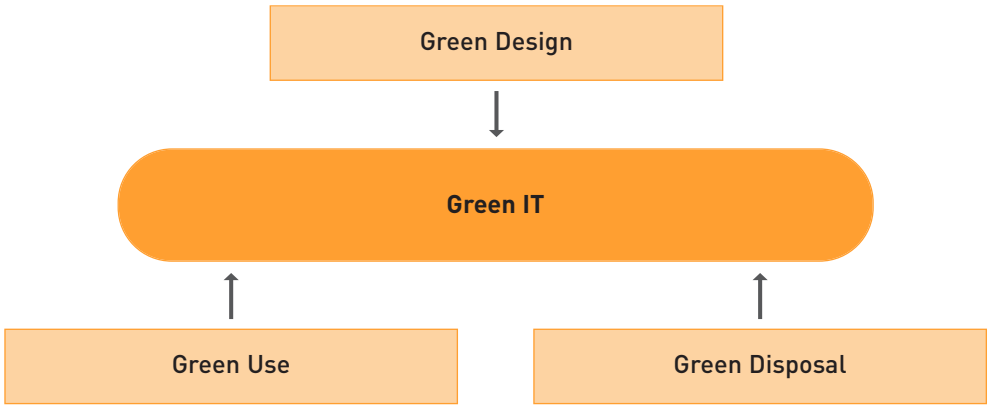

Figure 1: Dimensions of Green IT

ization aims at splitting hardware resources into several smaller virtual machines, enabling more than one virtual machine on a single hardware component, thereby increasing multitasking capability, fostering the utilization of servers, and improving energy efficiency. Enterprises can thus shut down servers and thereby reduce power usage leading to a significant cost reduction.

It is common practice for many companies to replace their older IT equipment with new, more energy efficient ones in an effort to become more environmentally friendly. However, this practice is not always the most environmentally sound solution due to the need to dispose the old IT equipment. Therefore, "Green IT disposal" aims at reusing, refurbishing, or recycling old IT equipment in environmentally sound ways.

Implementation of Green IT Concepts by Adopting Grid Technology

Most Green IT efforts take time to break-even since many enterprises cannot afford a short-term replacement of their existing systems with newer, Green IT solutions. Grid technology provides enterprises with the opportunity to build an own Green IT solution by interconnecting existing IT hardware into a Grid, thereby providing users and applications with immediate access to a large pool of IT resources, such as supercomputers, servers, desktop computers, storage systems, and databases. They can then be used as a unified resource. 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. 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).

As presented in Figure 2, the implementation of Grid technology addresses the three dimensions of Green IT: Green design, Green use, and Green disposal of IT.

Green Design

The migration to a Grid infrastructure can be seen as Green design of IT systems since companies can, e.g., build an Enterprise Grid to reduce power consumption of IT resources. In addition, enterprises can purchase energy efficient Grid resources from external services providers on a pay-per-use basis, called Cloud computing.

- **Enterprise Grid** – Enterprises increasingly need high computational power to meet dynamically changing and expanding business needs. This 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 company. 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.

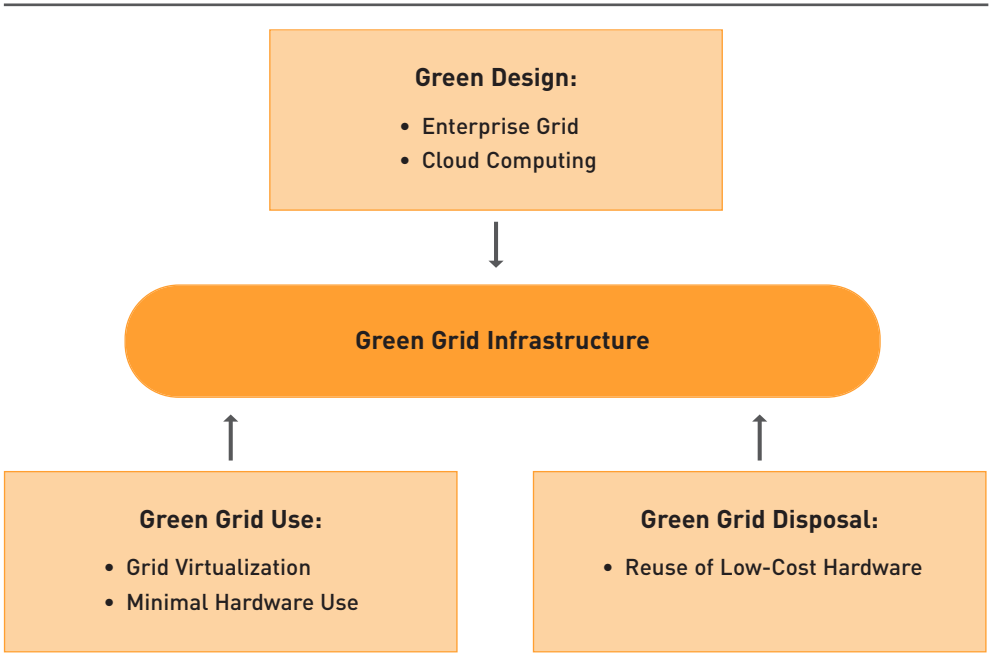

Figure 2: Grid infrastructure as an implementation of Green IT

- **Cloud Computing** – Besides the development and implementation of an own Grid infrastructure, Grid technology allows enterprises to purchase IT resources (most 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 abstract 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.

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 conscious concerning power consumption than enterprises that utilize less IT resources. Due to the exploitation of economies of scale in provisioning, powering,

cooling, and recycling of IT equipment, Grid services providers are able to invest in energy efficient practices and technologies. Therefore, future Grid infrastructures are likely to be far more power efficient than today. In addition, Grid providers increasingly adopt energy efficient servers, apply virtualization technology to maximize the utilization of hardware, and build new data centers in locations with specific climates (e.g., Iceland or Siberia). By using cold outside air for cooling the data center, there is less 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, air-cooled and therefore 50% more energy efficient than other comparably sized data centers. 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.

Green Use

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

- **Grid Virtualization** – Instead of 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.

  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. 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 to maximize the resource utilization.

- **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 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. Thereby, enterprises can further reduce expenses for new resources and reduce power consumption while providing significant computational and storage capacity to the branches.

Green Disposal

- **Reuse of Low-Cost Hardware** – Grid technology also contributes to the Green disposal of IT since it 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.

Conclusion and Outlook

Several parallels between Green IT requirements and the characteristics and benefits of Grid technology can be observed. Against this background, we presented 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.

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 is an initial approach to theoretically analyze the relationship between Green IT and Grid technology. 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, our results are of interest for enterprises planning to reduce power consumption of their IT systems while providing significant computational and storage capacity to their 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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