SEEKING SUSTAINABLE COMPUTING: THE ROLE OF CLOUD COMPUTING

David C. Chou
Department of CIS, Eastern Michigan University, Ypsilanti, Michigan 48197
Phone: 734-487-0054
E-mail: dchou@emich.edu

Amy Y. Chou
School of Information Technology, Illinois State University, Normal, Illinois 61790
Phone: 309-438-2804
E-mail: aychou@ilstu.edu

ABSTRACT

Sustainability becomes a common norm in recent years due to the discovery of uncertainty in various aspects of human life, society, and living environment. This paper intends to examine the development of IT sustainability in the IT industry, especially toward the creation of newly developed cloud computing technology.

Key words: Sustainability, sustainable computing, cloud computing, virtualization

INTRODUCTION

Sustainability becomes a norm in recent years since people in the world like to foresee changes and take action before any appalling things happen. The practice of sustainability is similar to the science of risk management, that is, it helps people identify relationships between issues and then proactively provide solutions to handle possible disasters that may happen in the future.

The IT industry has received heavy pressure to go green since computers’ production processes heavily utilize resources such as energy, water, and hazardous materials. In the mean time, their production process my frequently generate waste that can damage the environment. The movement of going Green computing is the practice of designing, manufacturing, and using computers, servers, and various peripherals to efficiently and effectively minimize the environmental impact.

Cloud computing is a newly formed area that has caught major attention in the IT industry. The major advantage of cloud computing practice is the offering of computing access as a utility form, which making computing capability through “service” oriented model. In general, cloud computing can be offered in the forms of Software as a Service (SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS), in which software, hardware, and storage capabilities can be achieved through “pay per use” paradigm.
There are a variety of advantages by adopting cloud computing paradigm. In addition to reach the goals of green computing such as cost saving and hardware deduction, cloud computing practice can generate economic, societal, and environmental values that parallel to the objectives of sustainability. This paper investigates the possibility of reaching sustainable computing by the adoption of cloud computing model.

The next section of this paper discusses the implications of sustainability and sustainable computing. The methods of identifying firm’s status of sustainable computing are conferred next. After that, this paper introduces and uses cloud computing as a candidate approach for reaching sustainable computing. A number of propositions are proposed in the next section. The conclusion is provided at the end of this paper.

**SUSTAINABILITY, GREEN COMPUTING, AND SUSTAINABLE COMPUTING**

**Sustainability**

The concept of sustainability has been discussed in literature. Brundtland (1987), in his famous “Our common future” report, described that “Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” The main focus of this Brundtland Report was on securing a global equity through redistributing resources towards poorer nations in the world. Areas of improvement such as peace, security, development and environment have also been proposed. For the sustainable development approaches, however, three fundamental components were emphasized: environmental protection, economic growth, and social equity. These components were concurred at the 2005 World Summit; it was agreed that the world needs to reach the reconciliation of environmental, social and economic demands – so called the "three pillars" of sustainability (United Nations General Assembly, 2005).

Pursuing sustainability in countries allows them to perceive and encounter various economic, environmental, and social benefits. Possible economic benefits generated from environmental sustainability are cost reduction, business (products and services) differentiation in the market, new market entry, image enhancement, etc. Possible environmental benefits can be energy consumption saving, waste reduction, health and life expectancy increasing, safety increasing, pollutant reduction, more resource reservations, etc. Finally, social benefits can be better social equity, regulation, and higher life quality, etc.

**Green computing**

Green computing contains a wide variety of areas and activities that related to energy saving and information technology based environmental sustainability. Murugesan (2008, p. 26) specified the following Green IT areas and activities:

- design for environmental sustainability;
- energy-efficient computing;
- power management;
- data center design, layout, and location;
• server virtualization;
• responsible disposal and recycling;
• regulatory compliance;
• green metrics, assessment tool, and methodology;
• environment-related risk mitigation;
• use of renewable energy sources; and
• eco-labeling of IT products.

The IT industry also feels the pressure of going green. IBM, for example, has developed a comprehensive working model to help create green business in the market. IBM’s framework consists of the following seven areas: strategy, people, information, product, information technology, property, and business operations (IBM, 2009). Other than that, literature in Green computing focused on methods of energy-efficient computing and green data center issues. HP (2010), for example, manufacturing its computers through “smart design (smart materials for energy efficiency or material innovation, careful design from the start or design for environment, and fewer materials, lower costs on packaging and transportation) and built-in efficiency (new standards such as ENERGY STAR qualified, high ratings lead to high savings through EPEAT Gold ratings, and greater efficiency built right in through efficient power supplies)”. The issues of green data center include data center impacts such as electricity consumption, energy conservation and strategy, selection of energy saved hardware, software, operations, and server, data storage device, virtualization methods, etc.

Sustainable computing

While green computing focuses on environmental sustainability, sustainable computing is a new wave of technological development that centers on service oriented effort toward sustainability. Harmon, Demirkan, Auseklis, and Reinoso (2010) used service-dominant perspective to derive the concept of sustainable computing (or sustainable IT). Harmon and others (2010) defined sustainable IT as “the application of IT knowledge and technologies for the benefits of customers and other stakeholders that enhances long-term mutual economic, environmental, and social well being”. Although the cost and energy savings was well accepted goals for meeting economic and environmental efforts, the social aspect of sustainability is a primary target to be accomplished for achieving sustainable computing. Therefore, the primary driver of sustainable computing in business community should be corporate social responsibility that applies to firm’s impact on economy, environment, and society at large (Harmon et. al, 2010; Zarella, 2008).

In summary, sustainable computing should have a higher vision than that of green computing. While green computing focuses on environmental efficiency, sustainable computing should fulfill the three pillars of sustainability: economic, environmental, and social demands. The business community should focus on their service to meet the above three pillars of sustainability. The IT industry must offer their services to meet the demand of economic, environmental, and societal values, which must be co-created with their customers. We can then reach the following conclusion:
A sustainable computing should consist of the following characteristics: service-orientation, provisions of efficient and effective services, and the capability of reaching the goals of sustainability – economical, environmental and social values.

The following section discusses the methods of assessing firm’s current position of implementing sustainable computing.

**METHODS OF ASSESSING FIRM’S STATUS OF SUSTAINABLE COMPUTING**

To assess firm’s current position in implementing sustainable computing, it can apply a strategic analysis to identify the external and internal environment of the firm. We will introduce Porter’s five-force model and stakeholder analysis for analyzing firm’s external situation and Porter’s value chain for examining firm’s internal situation.

**Porter’s five-force model**

Porter’s five-force model has been widely used to assess industry attractiveness and individual firm’s external environment. The attractiveness of an industry and a firm’s opportunities and threats are used to analyzing five forces (Porter, 1980). The five forces are:

1. The degree of existing rivalry
2. Threat of potential entrants
3. Bargaining power of suppliers
4. Bargaining power of buyers
5. Threat of substitute

In 2001, Porter has recognized the role of complements into his competitive advantage model. Complements are products that enhance the usefulness or desirability of a good in the market. The five-force model can be used to assess the impacts of IT that make the firm to be IT sustainable.

**Stakeholder analysis**

Stakeholder analysis is often used for both strategic and normative purposes. A strategic stakeholder analysis “emphasizes the stakeholder management issues that are likely to impact the firm’s financial performance, which a normative stakeholder analysis emphasizes the stakeholder management issues the firm ought to attend to due to their ethical or moral implications”. (Schilling, 2008, p. 112) Stakeholder analysis needs to identify all the parties (such as customers, employees, suppliers, stockholders, etc.) that will be affected by the firm, their interests to the firm, resources to contribute to the firm, and claims to the firm. The firm then analyzes these factors and then prioritizes which ones to be important to it. Stakeholder analysis is a suitable method to analyze firm’s IT usage and its impact to all stakeholders, this way can reveal the path of reaching sustainable computing.
**Value chain analysis**

Porter’s value chain analysis (1985) should be used to identify firm’s internal strength and weakness. This value chain model portrays firm’s activities into primary activities and support activities. The primary activities contain inbound logistics, operations, outbound logistics, marketing and sales, and service. The support activities contain procurement, human resource management, technology development, and infrastructure. Based on value chain analysis, each activity can be considered from the perspective of how it contributes to the overall value that produced by the firm, and what the firm’s strengths and weaknesses are in that activity (Schilling, 2008). The value chain analysis can be used to identify firm’s activities and its IT usage, and how IT creates value to the firm and the way to reach to sustainable computing.

**CLOUD COMPUTING AS AN EXAMPLE**

**Implication of cloud computing**

Cloud computing has gained a focal attention recently based on its combined features such as Internet delivery, virtualization, “pay per use” utility computing, elasticity, grid computing, storage capability, distributed computing, security, etc. The US National Institute of Standards and Technology has defined the most comprehensive definition of cloud computing ([http://csrc.nist.gov/groups/SNS/cloud-computing](http://csrc.nist.gov/groups/SNS/cloud-computing)):

> “Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics [on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service], three service models [cloud software as a service, cloud platform as a service, and cloud infrastructure as a service], and four deployment models [private cloud, community cloud, public cloud, and hybrid cloud].”

The above definition clearly identifies the characteristics, service models, and deployment models of cloud computing. The main sources of shaping cloud computing are the continuous expansion of broadband and wireless network, storage and mobile device costs deduction, and incremental advancement in Internet computing technologies. Web 2.0 technology, for example, has integrated into the architecture of cloud computing.

Companies such as Amazon (Amazon Web Services, Amazon Simple Queue Service), SimpleDB, Cloud Front, Microsoft (Microsoft Azure), Google, Global Data Vault, and Appnexus and GoGrid are examples of cloud providers in the market (Chee and Franklin, 2010) to support compute, storage, and application services. These public cloud providers allow the public to subscribe their services for enhanced collaboration, integration, and analysis on shared platform.
As indicated in the above definition, cloud computing can be classified into three service models:

- **Software as a service (SaaS):** An internet enabled application services, for example, Google Apps and Salesforce.com.
- **Platform as a service (PaaS):** It is foundational elements to develop new applications, for example, Google Application Engine.
- **Infrastructure as a service (IaaS):** It offers computational and storage infrastructure in a centralized, location transparent service, for example, Amazon.

### Technologies in cloud computing

Cloud computing system elements contain processing, network, and storage components. The cloud architecture includes three layers: infrastructure, platform, and application (Pallis, 2010). Cloud computing can be functioning through the following essential existing technologies: SaaS, inexpensive storage, inexpensive and plentiful client CPU bandwidth to support client computation, client algorithms such as HTML, CSS, AJAX, REST, client broadband, service-oriented architecture (SOA), and commercial virtualization (Creeger, 2009).

The addition of cloud computing causes some changes to current Internet technologies. First, content delivery networks need to fit in the new capability by changing their architecture, design, and implementation. Second, cloud providers must deliver content and services to end users with high data-transfer speed. Third, we need new standards to improve cloud interoperability. Fourth, cloud evolution will integrate Web 2.0 social networking features and functionality into its applications (Pallis, 2010). The development of the next generation cloud-based network must focus on the following areas: platform, software, and infrastructure as a service; cloud elasticity and availability; power-efficient computing; security and privacy; migration; management and configuration; interoperability; economics; new applications; and use scenarios (Pallis, 2010).

### Benefits of cloud computing

Cloud computing can generate the following benefits (Creeger, 2009):

- Large-scale multitenancy achieves significant economic advantage;
- Transforming high fixed-capital costs to low variable expenses;
- Flexibility;
- Smoother scalability path;
- Self-service IT infrastructure;
- Severely reduced disaster recovery cost;
- Common application platform enables third parties to add value;
- Increased automation;
- Release from ABI and operating-system dependencies and restrictions; and
- MapReduce enables new services.
The integration of cloud computing to the IT industry creates excitement and confusion. People feel excited about this newly added IT that may save user’s cost and energy usage. On the other hand, obstacles exist that could prohibit future opportunities for cloud computing (Armbrust, et. al, 2010). For example, business continuity and service availability, data lock-in, data confidentiality and auditability, data transfer bottlenecks, performance unpredictability, scalable storage, bugs in large distributed systems, scaling quickly, reputation fade sharing, and software licensing are the ten obstacles to be faced today (Armbrust, et. al, 2010).

As discussed in previous section, a sustainable computing should consist of the following characteristics: service-orientation, provisions of efficient and effective services, and the capability of reaching the goals of sustainability – economical, environmental and social values. We examine the mentioned three sustainable computing characteristics against cloud computing technology below.

1. **Service orientation**
   Cloud delivery is in utility computing pattern. It uses service oriented architecture (SOA) as main web technology. Its “pay per use” service model makes it a service oriented technology.

2. **Provision of efficient and effective services**
   Cloud computing clearly provides efficient and effective services to clients. In addition to that, it saves users a tremendous amount of IT expenses.

3. **Economic, environmental and social values**
   Cloud computing makes a significant impact to sustainability by generating values to economy, environment, and society. Cloud computing’s economic value is widely recognized by both vendors and clients. Because of scale of economy at vendors’ side, they can greatly cut down the service charge. It therefore benefits the client’s group. Since clients can eliminate needed hardware installation, it save both hardware and energy consumptions that contribute to environmental sustainability. Finally, cloud computing connects to social computing network that influences societal culture and therefore generates great value to society.

The above discussion briefly examines the possibility of cloud computing as a sustainable computing technology. We can deduce that cloud computing is in the move into the domain of sustainable computing. Since cloud computing is still under development, we can infer that its future technological advancement may make it better fit in the paradigm of sustainable computing.

Other methods to assess firm’s current status of sustainable computing will be investigated in the future study. We intend to use cases to study individual firm’s standing on adopting sustainable computing technology and possible value creation outcome.
CONCLUSION

The IT industry has received heavy pressure to go green since computers’ production processes heavily utilize resources such as energy, water, and hazardous materials. In the mean time, their production process may frequently generate waste that can damage the environment. The movement of going Green computing is the practice of designing, manufacturing, and using computers, servers, and various peripherals to efficiently and effectively minimize the environmental impact.

Cloud computing is a newly formed area that has caught major attention in the IT industry. There are a variety of advantages by adopting cloud computing paradigm. In addition to reach the goals of green computing such as cost saving and hardware deduction, cloud computing practice can generate economic, societal, and environmental values that parallel to the objectives of sustainability. This paper investigates the possibility of reaching sustainable computing by the adoption of cloud computing model.

After comparing the three characteristics of sustainable computing, cloud computing can be a good candidate to be sustainable computing. We can expect the future technological advancement to make cloud computing a truly sustainable computing.

References are available upon request.