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Review Article

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# Development of Green Cloud Adoption Decision Support Matrix Framework for Green ICTs in Higher Education Institutions

**Jara Muda* and Desalegn Aweke**

## Abstract

Information Technology in a modern arena have been playing a vital role in almost all walks of our today life. Due to the fast development and high level of greenhouse gases emission, the IT industry now a days has started thinking about Green IT strategies by Salient Data centers toward improving their environmental impacts. Green Computing, ICT or IT initiatives are now moving towards cloud or building their business applications on the cloud infrastructure. In addition to cost effectiveness, scalability and promised high uptime; green infrastructure and services have been increasingly adapted over cloud both in developing and under developed countries. Many research studies have investigated and analyzed that cloud computing is not inherently and always providing energy efficient solutions and services. Hence, products and services provided over clouds are also required to be green so as to minimize the adverse impact on environment. This paper analyzes the rational of Green ICT usage in higher educations and finds critical success factors for Green ICT implementation based on survey of selected educational institutes and interviews with academic key experts in the Universities of Ethiopia. Finally, the paper produced a development of Green Cloud Adoption Decision Support Matrix Framework for green ICT in higher educational institutions. The paper also implemented an energy saving technique to reduce energy consumption levels of the cloud data centers where ICT products as services runs in real sense. As an outcome, Green Cloud Adoption Decision Support Matrix Framework that helps the cloud service users to select most feasible Green cloud-based ICT products and services is produced. In order to save environment and its effect on human life this research can be utilized as a great contribution of new knowledge in green ICTs design and deployments in HEIs.

**Keywords:** Cloud Computing; Cloud Broker; Green ICT; Higher Educations; Framework; Emerging Technology energy-efficient

## Introduction

The countries in the World are challenging with the changes in climate and weather due to increasing emission of greenhouse gases. It is creating droughts in some countries and floods in others. It's slowly pushing global temperatures higher and posing serious problems to the planet. To prevent the buildup of greenhouse gases within the atmosphere, global emissions would need to stop growing.

Electricity could be a major explanation for global climate change. Reducing power consumption could be key to reducing greenhouse emissions and their adverse impact on the environment and heating [1,2]. ICTs affect the environment in several ways. Each stage of a computer's life, from its production, up to its disposal, leads to the serious problem of environments human being lives in. The productions of various electronic and non-electronic components consume electricity, raw materials, chemicals, water, and generates harmful waste which all these directly or indirectly increase greenhouse emissions and impact the environment [3]. The whole voltage consumption by servers, computers, monitors, data communications equipment, and cooling systems for data centers is steadily increasing [1-3].

The increase in energy consumption ends up in increased greenhouse emissions. Energy efficiency is increasingly important for future information and communication technologies (ICTs) [4-6] and the most potential for the future Green ICTs. The increased usage of ICTs, along with increasing energy costs and therefore the have to reduce greenhouse emissions is an important strategic initiative for Green ICTs that may decrease the energy consumption of computing technologies [7].

The use of ICTs in Higher education Institutions are cause of carbon dioxide emission, high energy consumption and hazardous waste production and at the same time, makes the Planet noxious and unsustainable in different corners. To make the ICT Green in Higher Education Institutions, integrating ICT with Emerging Technology like IoT, Cloud Computing are novelty and researchable area for technocrats and researchers. Cloud computing has currently received considerable attention, as a promising approach for delivering ICT services by improving the use of information center resources [6].

In theory, it's been critically argued by several researchers and scholars that cloud computing will be an inherently energy-efficient technology for ICTs as long as it's potential for significant energy savings. The integration of Cloud Computing trend with ICT can be ideal for replacing software manually installed on campus computers with applications delivered via the internet is driven by aims of reducing Higher Education Institutions (HEIs) ICT complexity and cost. Cloud Computing could be a technological innovation and also used for both reducing ICT costs for the HEIs and eliminates many of the time-related limitations for workers, Experts within Universities ICT center, Teachers, and students, making learning tools accessible for a larger number of students while makes environment sustainable by reducing E-wastes and Carbon emission so as to make Green ICTs.

Through the utilization of huge shared virtualized data centers, Cloud computing can give large energy savings and have a greater contribution to making ICTs green within the higher education institutions. How and in what ways; the cloud computing technologies will be adopted in universities of developing countries like Ethiopia are still the unanswered question. During the study, BHU's ICT was examined for the current status of greenness and ignored factors towards green ICTs. The most focus of the study was to research, how energy-efficient or Green cloud computing adoption can increase energy efficiency? On the opposite side; so as to judge how power reduction mechanism can enhance the greenness of the cloud data

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center? The experiment was conducted using cloud simulation. The experiment and simulation by toolkit called Cloud Sim shows that the incremental growth in resources and services can increase energy consumption and leads to higher $CO_2$ emission rate. Thus, this experimental analysis using DVFS can be a great instrumental support to reduce energy consumption at data centers and also can reduce the $CO_2$ emission. Within the study, efforts are made to answer the subsequent technical questions-

- What ICTs strategies have considered as green ICT aspects in HEI?
- Are the proposed Green Cloud Adoption Decision Support Matrix Framework for Green ICTs being an answer for step towards green ICTs development and deployment?

## Review of Related Works

Different institutions, organizations, and countries recognized benefits and efficiency of using cloud computing. Many of them are adopting Green cloud computing services so as to make sure efficient use of power and making the ICT sectors environmentally sustainable. The studies by Fatima Zahra [8,9] highlights the importance of and the role played in reducing carbon emissions by the developing countries and the way forward to reducing Carbon emissions by creating awareness on Energy efficient Cloud Computing Infrastructure among ICT Sector of Developing Countries. The use of information technologies in developing countries is not as important as in the developed ones. A recent research article by Deepanjan Sen and Dilip Roy Chowdhury [10] shows that, moving salient business applications to emerging technology like cloud computing platform can reduce carbon footprint of organizations and increase sustainable development in Greenness of ICTs Sector within organizations. The study found that, for large deployments, cloud solutions can reduce carbon emissions by more than 30 percent. The benefits are even more for small businesses; energy use and carbon footprint can be reduced by more than 90 percent. The studies by Wenjuan Zhao [11,12] describes that cloud computing is one of the fast spreading technologies for providing utility-based IT services to its users. Large-scale virtualized data-centers are now encouraged to establish for meeting this requirement. Djouhra Dad [13] Presented challenges in cloud with respect to energy and cost while meeting Services Level Agreement and also focused on the energy efficient management of data center resources for cloud computing and Green Computing. The study discussed energy-efficient architectural principles for cloud management, resource allocation and scheduling policies for Green cloud considering QoS (such as responsiveness, performance, and availability), characteristics of power usage by devices and novel software technology for cloud management. This research used toolkit of cloud computing for simulation of the results. In addition to it, research [14] proposed a client-oriented Green Cloud Middleware to assist managers in better overseeing and configuring their overall access to cloud services in most energy-efficient way. In this research, whether to use local machine processing, private or public clouds was smartly handled by the middleware using predefined system specifications.

Till date HEIs in Ethiopia; has no focus on green factor consideration during planning for ICTs and procurement processes. Research studies regarding green ICTs and technologies to make ICTs green are almost missing. Only a few studies about cloud computing adoption for cost effectiveness, scalability and ease of maintenance have been done. After rigorous investigation and analysis of salient related literature review from relevant sources; it has been observed that there is an critical shortage of research studies in the focused area i.e. Green Cloud Adoption Decision Support Matrix Framework for Green ICTs in Ethiopian HEIs especially for developing countries. Therefore, this research work is worth doing and can add value on the journeys that the higher education institutions make to migrate from Local server or ICT Data Center within Each Universities or organization to Emerging computing infrastructure so as to make our future environment very attractive and Green to live in as well as to save our future Generation.

## Research Design and Methodology

By the nature, this study is exploratory and Constructive type of research design with a mixed approach (Qualitative and quantitate). Initially this study starts with an effort to explore the feature and performance of existing ICT usages, E-wastes management strategies in HEI, the level of awareness on the usage of ICT for greenness of Environment and showing the way forward that have no adverse effect on the Environment. It explores the answers for the questions raised in the study. Further the study constructs the Green Cloud Adoption Decision Support Matrix Framework for Green ICTs. Hence this study is exploratory cum constructive. A Portable EDrawmax tool is used intentionally by the researcher for designing and developing a proposed framework. For the simulation of the result, the Cloudsim toolkit was used throughout this research work.

## Designing and developing a proposed green cloud adoption decision support framework

- This study proposed Developing Green Cloud Adoption Decision Support Matrix Framework for Green ICTs In Higher Education Institutions and selected BHU as a case study. The framework consists of: 1) Cloud Service User/ Consumer (BHU ICT), 2) Energy Efficient Cloud Service Broker (EECSB), 3) Energy Efficiency Information Directory (EEID), and 4) Cloud Deployment Model Selection. The Figure 1 framework that a user can use for selecting energy efficient cloud services via energy efficient cloud service brokers. As illustrated in Figure 1, the proposed Framework Components are as follows-
- Users submit their cloud service requests to Energy Efficient Cloud Service Broker (EECSB) that manages the selection of the greenest cloud provider to serve the user requests.
- EECSB gets the current status of all the information related to energy efficiency of cloud service providers, registered in to energy efficient information directory.
- EECSB analyzes energy efficiency parameters and carbon emission of all cloud service providers that are offering the requested cloud services.
- Then EECSB selects a cloud provider and request green SLA negotiation between user and cloud service provider.
- EECSB allocate services to the appropriate cloud service provider from Cloud Deployment model selection on behalf of the user.
- If no exact match is found for the request or Green SLA between the user and cloud service provider failed, the EECSB selects another Energy efficient cloud service provider and reiterates the negotiation process.

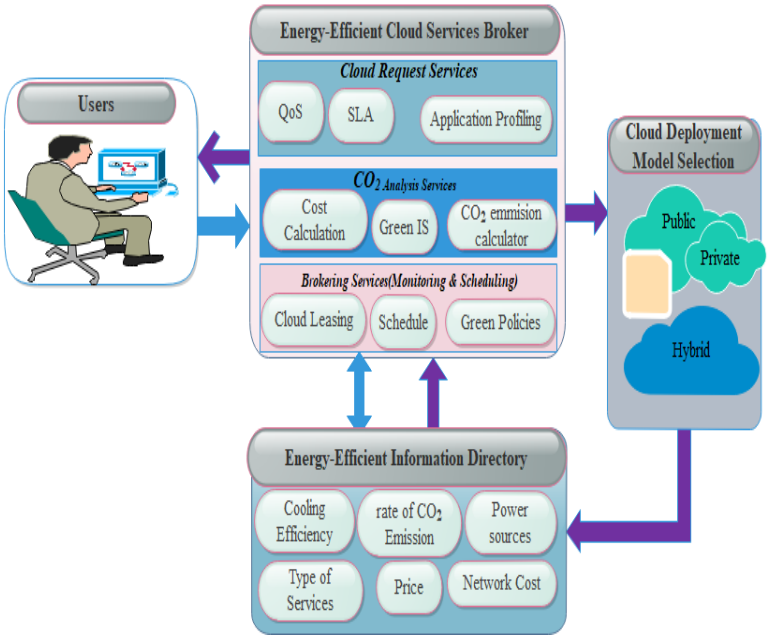


**Figure 1:** Proposed Green Cloud Adoption Decision Support Matrix Framework for Green ICTs in HEI.

## Research Experiment and Analysis

### Current ICTs usage

Interviews and direct observation mechanisms were used for collecting the facts ICT usage weather it is green or not. Following data and facts were collected through interview and direct onsite observations- 1) Awareness on energy efficiency, 2) Server utilization, 3) Under-deployment of power management software and 4) Disposal of E-waste. As indicated below in the Figure 2, the interview responses from ICT officials of BHU show that the green ICT usage maturity level is at its early stages.

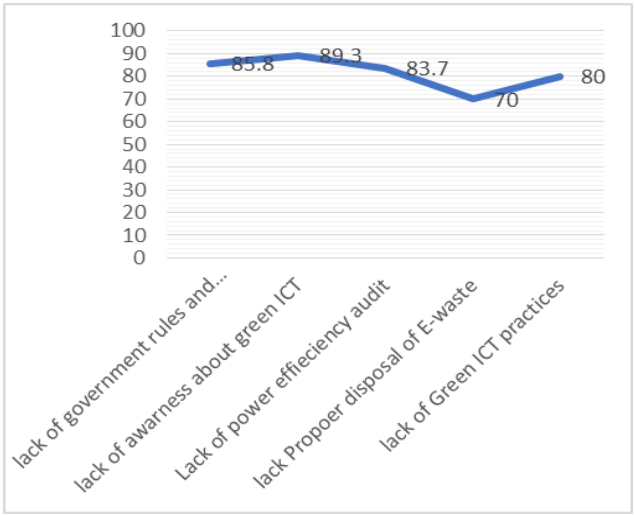


**Figure 2:** Current green ICT usage in BHU as per the respondents.

### Framework Simulation Experiment Using Cloud Sim

**Cloud Sim Toolkit:** In this research, in order to analyze power consumption and power saving in cloud $NS_2$ and uses $C^{++}$ for programming would have been the perfect tool for this research as it measures the details of consumed energy in the components of a cloud data center.

### The Experimentation Process

In this experiment the implementation stage displayed outputs of different simulated cases of a cloud data center using the Cloud Sim toolkit, with the objective of assessing the experiments which is based on the variations of energy consumption metrics for scenario with energy saving techniques as against computing environment, the particular service the researcher focused here is energy reduction/ saving techniques in cloud deployment framework. By performing experiments in a controlled environment, the organization can identify performance bottlenecks, pre-test expected outcome of implementation using different scenarios and develop the most viable implementation technique for green cloud for ICTs. Cloud sim has been selected as the simulation tool for this study but there was another option that was considered for this research was Green Cloud which sits on top of scenarios without any form of energy saving technique. The ten tests were conducted with scenarios of DVFS mechanism deployment initially and then ten tests without any form of power aware mechanism. The experiment was executed based on the value settings of VMs, hosts and cloudlets. An initial value of 10 hosts, 20 VMs and 20 cloudlets were used. Due to the randomness of the toolkit each test runs 4 times to produce the mean energy Consumption metrics using excel sheet (Tables 1 and 2).

### Analysis of the results

**Power aware mechanism & experimental results:** The objective of this section is to evaluate how increasing the number of resources and services in a data center reflects on energy consumption. It was analyzed that how the deployment of a DVFS mechanism can contribute towards reducing energy consumption compared to a data center where a DVFS mechanism is not deployed. The values were set to the initial default value as stated earlier and doubled, recorded

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**Table 1:** Experiment value of power aware mechanism (DVFS) enabled.

| | Run 1 | Run 2 | Run 3 | Run 4 | Mean Value |
|---|---|---|---|---|---|
| **Experiment 1** | 0.252 | 0.251 | 0.244 | 0.252 | 0.25 |
| **Experiment 2** | 0.504 | 0.493 | 0.502 | 0.502 | 0.5 |
| **Experiment 3** | 1.013 | 1.023 | 1.014 | 0.987 | 1.01 |
| **Experiment 4** | 2.122 | 2.102 | 2.092 | 2.082 | 2.09 |
| **Experiment 5** | 4.204 | 4.184 | 4.177 | 4.212 | 4.19 |
| **Experiment 6** | 8.444 | 8.414 | 8.435 | 8.394 | 8.42 |
| **Experiment 7** | 16.943 | 16.903 | 16.932 | 16.941 | 16.92 |
| **Experiment 8** | 33.861 | 33.833 | 33.911 | 33.921 | 33.88 |
| **Experiment 9** | 67.682 | 67.675 | 67.683 | 67.682 | 67.68 |
| **Experiment 10** | 101.461 | 101.458 | 101.467 | 101.467 | 101.46 |

**Table 2:** Experiment values of non-power aware.

| | Run 1 | Run 2 | Run 3 | Run 4 | Mean Value |
|---|---|---|---|---|---|
| **Experiment 1** | 0.871 | 0.87 | 0.869 | 0.869 | 0.86 |
| **Experiment 2** | 1.77 | 1.779 | 1.78 | 1.781 | 1.77 |
| **Experiment 3** | 3.58 | 3.579 | 3.577 | 3.58 | 3.57 |
| **Experiment 4** | 7.281 | 7.294 | 7.262 | 7.299 | 7.284 |
| **Experiment 5** | 14.582 | 14.499 | 14.582 | 14.521 | 14.54 |
| **Experiment 6** | 29.711 | 29.721 | 29.699 | 29.71 | 29.71 |
| **Experiment 7** | 59.692 | 59.69 | 59.661 | 59.643 | 59.67 |
| **Experiment 8** | 119.435 | 119.621 | 119.435 | 119.421 | 119.47 |
| **Experiment 9** | 242.291 | 242.298 | 242.299 | 242.308 | 242.29 |
| **Experiment 10** | 364.192 | 364.193 | 364.19 | 364.189 | 364.19 |

and then analyzed for variations in energy consumption. The experiment based on Energy consumption value with DVFS enabled technique shown in Figure 3. The minimum and default value for this experiment is 10 hosts, 20 VMs and 20 Cloudlets.

**Experimental results in absence of power aware mechanisms:** The objective of this section is to evaluate how energy consumption value increased in the data center that didn't use energy reduction mechanism with compared to the data center that uses energy reduction mechanism like DVFS. Increasing the number of resources and services in a data center reflects on energy consumption. The values were set to the initial default value as stated earlier and doubled, recorded and then analyzed for variations in energy Further in the Figure 3 increasing number of hosts, cloudlets and virtual machines clearly indicates the increase in the power consumption in the data centers. From experiment 1 up to experiment 5 doubling the resources just doubles energy consumption value. Further it has been observed that after experiment 6 the energy consumption value increases more than double i.e. normal and proportional increment in energy consumption deviates from normal pattern to the abnormal increase. This concludes that the incremental growth in resources and services can increase energy consumption and leads to higher $CO_2$ emission rate. Consumption like the experiments done on DVFS enabled.

The experiment based on Energy consumption value without any power aware mechanism enabled shown in Figure 4. The minimum and default value for this experiment is 10 hosts, 20 VMs and 20 Cloudlets. As the simulation result shows; a data center without any power reduction mechanism can have greater energy consumption rate starting from experiment 1. Energy consumption value of a data center without power aware mechanism increases almost double up to experiment 5 and more than a double after experiment 6. The difference between the 2 scenarios can be seen based on the calculation of the mean values of the energy consumption metric.

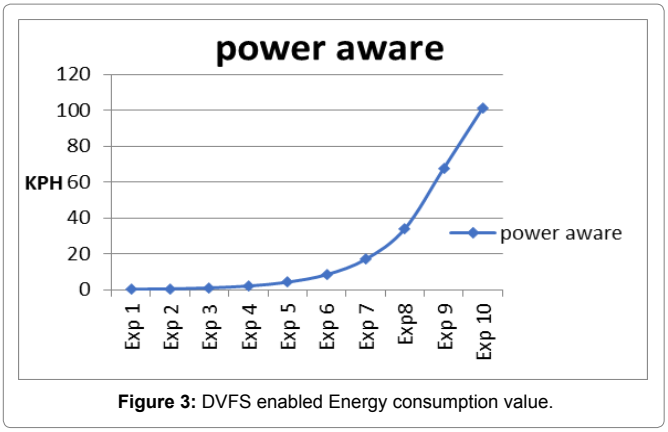


**Figure 3:** DVFS enabled Energy consumption value.

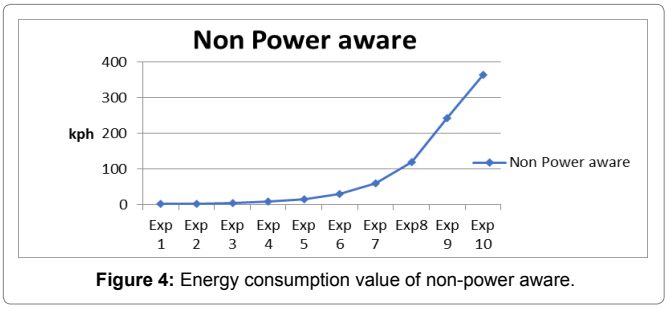


**Figure 4:** Energy consumption value of non-power aware.

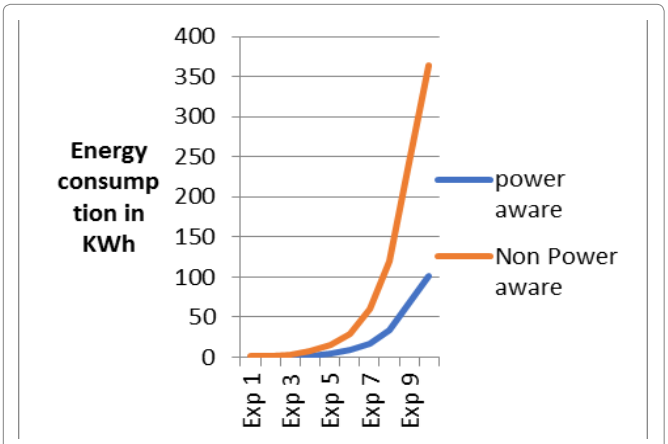


**Figure 5:** The simulation results of non-power aware versus Power aware.

In experiment 10 the energy consumption values of DVFS enabled and non-power aware is 101.46 and 364.19 respectively. This shows that the difference in power consumption in non-power aware data center is 300% greater that of power aware mechanism enabled. The Figure 5 shows the comparative analysis of power aware and non-power aware simulation results which clearly indicates that if these technique are used in analyzing the demand of products and services required from cloud infrastructure then it can help decision making tier i.e. Energy Efficient Cloud Service Broker to select energy efficient data center in terms of services, products and to make ICT usage greener. Thus, this experimental analysis using DVFS can be a great instrumental support to reduce energy consumption levels at data centers and also can reduce the $CO_2$ emission. In order to save environment and its effect on human life this research can be utilized as a great contribution of new knowledge in green ICTs design and deployments in HEIs.

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## Conclusion

The primary goal of this research study was to investigate and analyze the ICTs usage by using a case study of organization BHU with green factors consideration and selecting a most appropriate technology based products and services that can ensure energy efficient usage of ICTs and enhance the organization's ICT usage one step towards green or energy efficient products and services. As a final research contribution, the study designed and developed Green Cloud Adoption Decision Support Matrix Framework for Green ICTs that is assumed to be a most suitable for educational institution like BHU and will give a new knowledge-based decision support base line for the organization having similar types of structures and operations in developing or under developed countries. After discourse analysis of investigated facts, observations and case-based simulation of different conceptual and technical artifacts and frameworks; Green Cloud Adoption Decision Support Matrix Framework for Green ICTs has been produced for advising energy efficient or greener ICT products or services with assurance. In this research study newly introduced energy directory will be able to provide information about the $CO_2$ emission rate, the power source used by cloud service providers along with other green offers announced by cloud service providers to the users or decision makers. The designed framework is just a road map for the adoption of cloud computing for energy efficient usage of ICTs. Thus, the Energy Efficient Cloud Service Broker integrated with third party outsourced Green Information Directory can be a significant middle tier decision support system to help users, organizations and decision makers.

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