Green ICT Framework for Ethiopian Higher Educational Institutions

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Abstract

The higher educational institutions (HEIs) of developing countries have two most important challenges i.e. cost effective ICT solutions, aligning ICTs with modern technologies and adopt sustainable approaches to significantly reduce the power consumption. An essential aim of the paper is to determine how to reduce power consumption & carbon foot prints, apply reduce, reuse and recycle practices for ICT equipment's in HEIs. The developing country like Ethiopia is one of the countries where power scarcity is a big challenge and required to develop strategies that can encourage power savings along with green ICT strategies. Developing countries also face numerous challenges like strategic alignment in energy efficient techniques, refurbishing, reusing and recycling of the ICT equipment with standard scientific practices. Developing continent countries like African HEIs are still reluctant in adopting the energy efficiency standards practices. As a primary observation, it was observed that these HEIs are still away from the wide range adoption of energy efficient mechanism and green standard practices for ICT equipment. This research paper analyzed the current green ICTs usage in HEIs and selected three universities as sampling sites for primary data collection, case observation, and analysis. Finally a green ICT framework for reducing power consumption, reusing, refurbishing and recycling the ICT equipment in HEIs is proposed for adoption. The research performed experimental analysis in simulated environment using dynamic voltage and frequency scaling technique (DVFS) with VM migration. The simulated results found that the total consumption of energy by the ICT center is approximately reduced by 95 % for the specified configuration of the ICT center equipment. The results showed the significant contribution to reduce energy consumption, minimize environmental impacts and reduce the Co2 emission especially in the selected university ICTs.

Keywords: Green, Computing, DVFS, HEIs, ICT, Data centers etc.

1. Introduction

Today one of the most widespread and global issues and concerns are the green or energy efficient information and communication technologies (GICTs) and their long-term sustainability. The growing level of energy consumption in salient sectors, typical level of

global warming and the growing e-waste have led to pay much consideration in green computing practices or green ICTs by the worldwide governments organizations and businesses houses. As a matter of facts, it is a substantially important, morally desirable and environmentally promising for sustainable improvement [1]. As per the report of the International Federation of Green ICT and IFG Standards; energy efficient computing, Green computing, Green ICT or sustainable IT, is the study and practice of environmentally sustainable computing. Although, the Green ICT is an innovative approach where the ICT systems and services related to the environment protection and sustainability are investigated and analyzed. In general, it entails the scientific practices to achieve the desired level of corporate social responsibility by minimizing the emission level of carbon footprints, scientific waste management of ICT and saving energy consumption. In addition, the green computing is the method of implementing frameworks, policies and procedures that support both individual and business-oriented computing needs in an ecological and sustainable manners. It increases the life cycle of the systems and devices along with the efficiency of ICT resources and also significantly minimizes the energy consumption so as to minimize the adverse impact on the environment [2].

If the design, development, deployment and disposal of the ICT equipment is Green then the environmental responsibility towards sustainable usage of the computing and communication devices can be said that it's aligned with the societal needs of the sustainability. If it does not damage the natural resources and minimizes the GHGs then it's assumed as sustainable. These advices a typical phase of recyclability of ICT equipment, reducing GHGs, proposing alternative tools and technologies in numerous arenas, towards generating center of economic activities around technologies so as to increase the benefits to environment. The massive amount of computing and communication devices manufactured globally have a direct impact on environment. Also, the scientists are trying to investigate and analyze that how the negative impact of computing and communication can be minimized and the natural resources can be protected.

Higher Educational Institutions and their ICT centers in developing countries in general and Ethiopia as a case are still away from the judicious attention on energy efficiency standards and green practice considerations. These ICT centers are still running. A current research on the green or sustainability issues, concerns and energy efficiency in the selected Higher Learning Institutions of United Kingdom (UK"s HEIs) clearly discovered that computing and communication devices and paper printings are major contributors. This is approximately 66% of the total energy consumption of the ICT equipment in the HEIs of UK [3] [4] [5].

Also, the HEIs ICT centers are still running with the old models and therefore consume large amount of energy in the countries like Ethiopia. It has been observed in several institutions that Ethiopia is one of the developing countries that use power without focusing on proper green ICT equipment management strategies. In Ethiopia, there is a lack of environmentally responsible use of ICT equipment like computers and related ICT resources. Worldwide exponential increase in the demand for computational energy has led to the formation of large-scale issues and concerns in ICT centers of numerous educational institutions and other

sector organizations. It's obvious, these sectors are consumers of huge amounts of energy and resulting into high working costs with high level of emission of carbon dioxide [4] [7] [8].

The increased dependency of academic and research activities on ICT, creates a thrust for using ICT infrastructure efficiently and to alleviate the sustainability issues and challenges. This level of greenness can be attained by certifying that the systems and software applications should be energy efficient. These remedial actions will not only reduce the emission of greenhouse gases but also the environmental pollutions, and carbon footprints can be significantly reduced. A research [5] revealed that green ICTs and green practices are not just only need anymore; but these are sustainable responsibilities with accountabilities. Today the entire world is at high risk of global warming and the greenhouse gases are the most important factors. It is clear the that computing and communication i.e., ICT equipment's are made up of the toxic materials like chromium, cadmium, lead and mercury. These materials produce harmful chemical substances and responsible for the water pollution and contamination in the air and waterways thereby causing high level of global warming and climate change. They are critically damaging the respiratory systems of human generation and causing salient skin diseases like cancer. Based on the thorough investigation, observation and analysis of the review of literature facts; Ethiopian HEIs are still lacking in energy efficient and green strategy standards to be considered and adopted during the planning for reducing power consumption, refurbishing or reusing the old devices and planning for recycling the ICT equipment managed under ICT centers. The HEIs ICT centers are lagging behind in terms of energy efficient and green strategies. This research could be a valuable base guideline for future Generation ICT Centers through analytics of the current state of the art systems, strategies and practices of the power management and will create a new paradigm of energy efficient ICT centers in developing countries like Ethiopia.
As a major contribution, this research paper analyzed the current green ICTs usage and practices in Ethiopian HEIs and selected three universities as sampling sites for primary data collection, case observation, and analysis. Finally a green ICT framework for reducing, reusing, refurbishing and recycling the ICT equipment in HEIs is proposed for adoption. The research performed experimental analysis in simulated environment using dynamic voltage and frequency scaling technique (DVFS) with VM migration. In this these simulated results it was revealed that the total energy consumption of the salient devices at the ICT center is nearly declined by 95 % for the given set of configurations in ICT equipment of the ICT center. The results showed the significant contribution to reduce energy consumption, minimize environmental impacts and reduce the Co2 emission especially in the selected university ICT center. This research can be used as a baseline for designing next generation data centers i.e. green data centers and their policy making in the developing countries like Ethiopia where the thought and concept of green computing and ICTs are in its infancy stage. This research can help them to align their ICTs and data centers with global standards and practices.

2. Review of Literature

The prime objective of this paper is to review studies and efforts of HEIs/higher educational institutes on Green ICT strategies, systems and practices towards reduction of power consumption, re-usage of old devices, and recycling of the retired devices using standard green ICT strategies. Review of concepts and related researches are elaborated with the scientific concepts related and critically evaluated the researches accomplished prior to this study to find a crystal clear research gap between existing and the proposed. For supporting the proposed research study, a number of literatures have been reviewed in the areas of traditional framework to realize technical, theoretical and economical background and weaknesses of educational organizations involved as a case in this study.

In a research [6], the contribution of the researcher is relevant because of it focuses on reduction of energy consumption. The energy consumption problems at ICT centers are focused only on desktops in this paper. It implies a single equipment of ICT center and single solution. The paper does not cover the other devices that consume more energy like laptop, printer, scanner, photocopier and others.

Another study [7] is relevant to the proposed paper since answering the technical level questions about the existing computing infrastructure and how to make green ways the resources used. It is required in our paper for improving and extending the feature utilization over next generation virtual desktop based computing and communications. The paper failed to contemplate green ICT framework for reduce, reuse and recycle of ICT equipment.

A research paper [8] focuses only on analyzing the factors which affect the systematic adoption of energy efficient or green computing systems and devices in the universities of the Gulf countries. However, this research clearly futile to contemplate green or energy efficient ICT frameworks for the aforementioned reduce, reuse and recycle of ICT systems and equipment.

Another research study [9] is focused on investigating and analyzing the factors that affect the adoption of energy efficient or green computing in the Gulf universities. In this researcher could not provide any well-designed energy efficient or green ICT framework.

A paper [10] also highlighted some of the methods that can be followed by programmers while developing software. The paper emphasizes on various strategies in the design of an energy efficient data center. The paper stresses on green computing researcher’s view towards next generation computing and evaluate the different approaches to these problems.

This research [11] [12]are relevant to our paper but it only paper stresses on green computing and researcher’s view is only on future generation systems and evaluated the different approaches only in HEIs. The research focuses on providing the awareness about green computing and this is only a single parameter about greenness.

The research papers [13] [14] found relevant and focused on recycling as strategy for green computing and promising results are achieved on the data centers. These data centers consist of servers with the capability of reducing their energy consumption by software defined techniques. This option is advisable but usually increases investment cost of the data centers.

After rigorous study and analysis of related literature from relevant sources; it has been observed that there is a severe shortage of research studies in the focused area for designing a green ICT framework for higher educational institutions (HEIs) in Ethiopia.

3. Research Design and Methodology

3.1 Research Methods

To achieve the research objectives and answer the research questions, this research study used different approaches and methods for gathering the relevant data in the area of the research. The researcher used a mixed research approach (mix of qualitative and quantitative) for gathering appropriate data using technical observations and survey and interview questionnaires for inputs of end users community and experts.

3.2 Selection of Simulation Tools and Technologies

In this section numerous software and system designing tools and techniques were used to accomplish the targeted research tasks. An open-source Cloud Computing tool (i.e., CloudSim) was selected for simulating the energy efficiency in newly proposed framework. A Microsoft E-draw max tool is used for designing the conceptual framework and Google Form is used for collecting the data via online line Survey. These tools are selected based on parametric suitability assessment and illustrated in the figure 1.

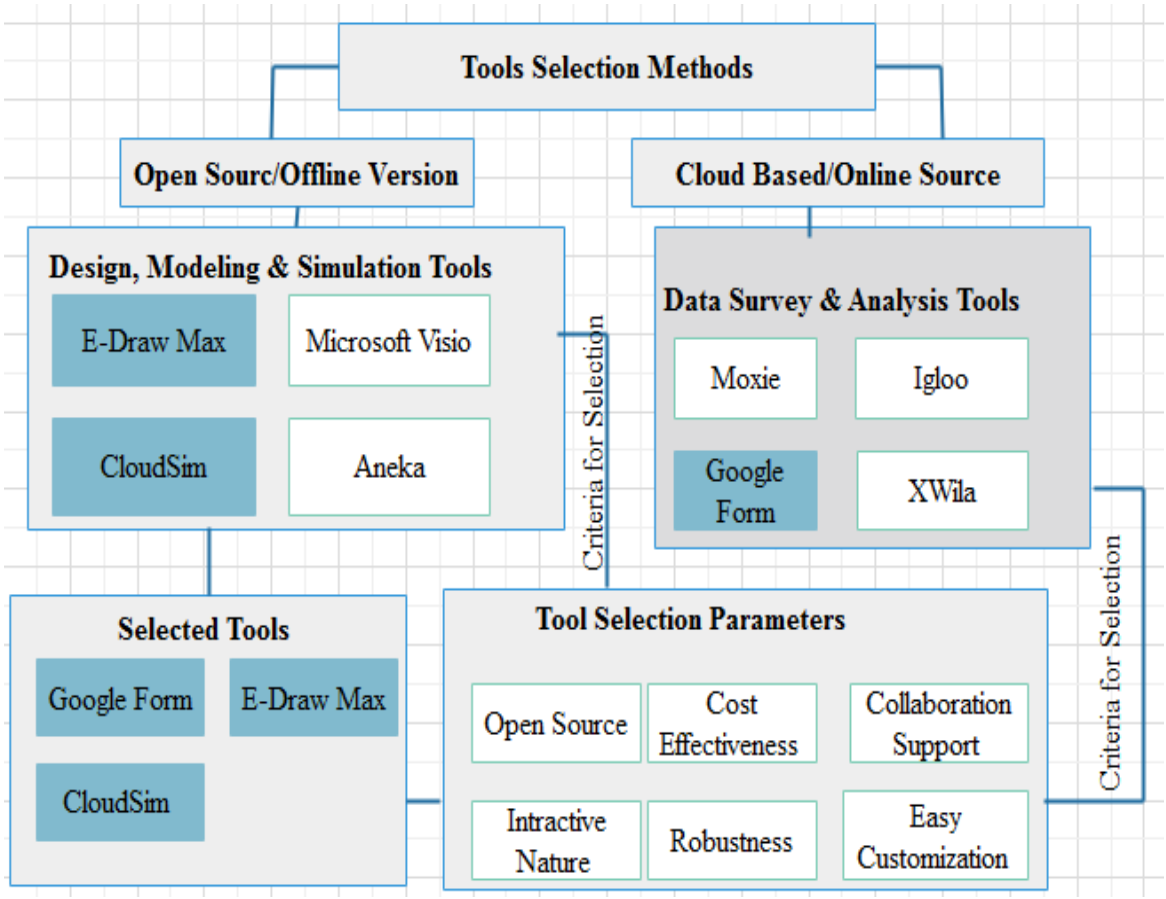

Figure 1: Selection Method for Software Tools and Technologies

4. Research Experiment and Analysis

4.1 Current ICTs usage

As illustrated in the Figure 2, the interview responses from targeted respondents of selected universities like AMU, WSU and WCU showed that within the HEIs ICT centers, there is no any energy efficient/green strategy that can be enforced and adopted for reducing the power consumption by ICT equipment, promote refurbishing/ reuse and recyclability of defunct ICT products. Accordingly, the greenness maturity level is found at its primary stage. As shown in the Figure 2, it is revealed that 86.2% experts and professional clearly point out the lack of legal frameworks; 64.6% respondents showed lack of education systems review policy; 60% respondents point out the lack of human personnel skills and qualification; 47.7% experts and professionals point out the lack of poor decision-making process; 43.1% experts and professionals clearly revealed the lack of funding; 41.5% experts and professional indicated the fast changes in the technology. The complete scenario revealed that the usage maturity level is at its primitive stage which hinders the transformation of ICT center equipment from non-green to green in HEIs ICT center in general and Ethiopia as a specific case**.**

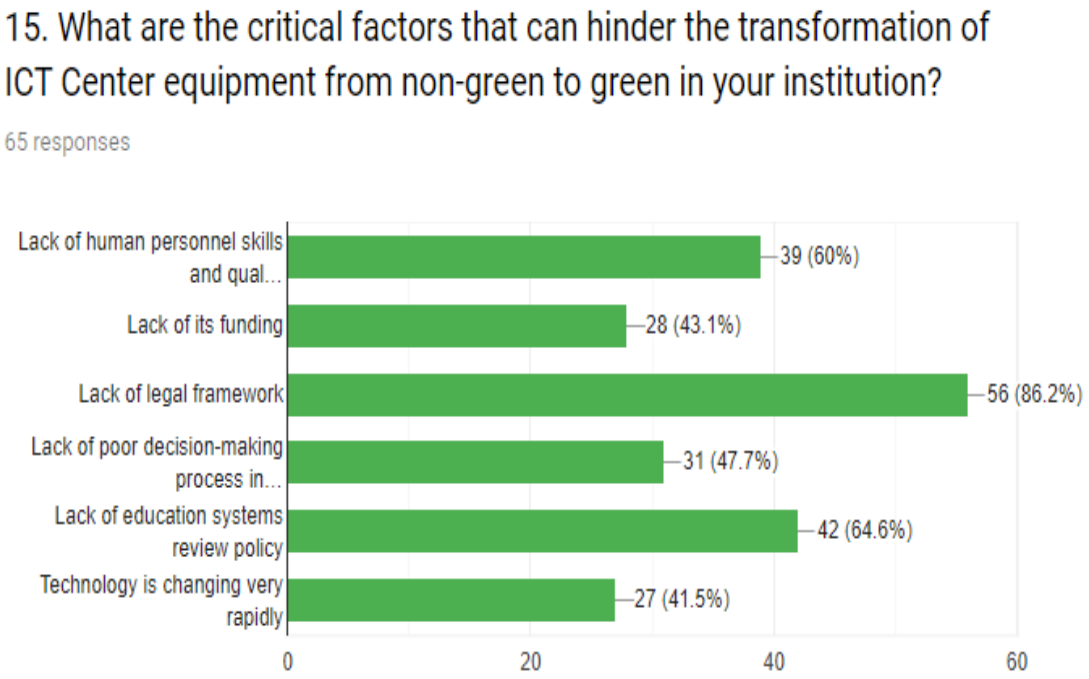

Figure 2: Status of current green ICT usage based on respondent's responses

4.2 The Proposed Green ICT Framework for HEIs in Ethiopia

The essential aim of this framework under study was to determine how to reduce power consumption, apply refurbishing, reusing and recycling practices for ICT equipment's in HEIs**.** This framework consists of different components i.e. green purchasing framework, green design framework, green usage framework, green printing practice framework and green disposal (reduce, reuse & refurbish and recycle) as shown in the converged framework in Figure 3.

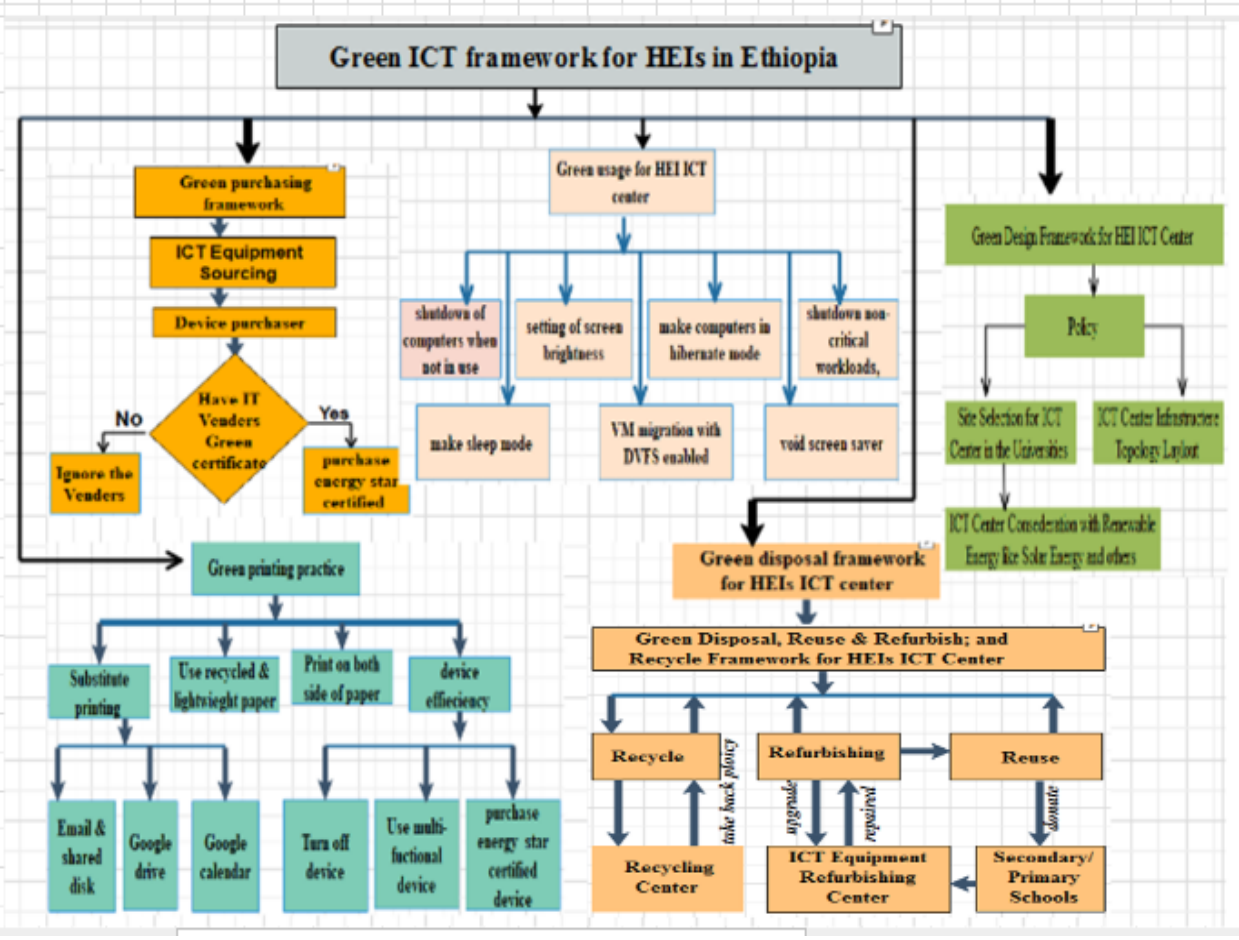

Figure 3: Proposed Green ICT framework for HEIs

4.2.1 The essential components of the Framework-

4.2.1.1 Green purchasing framework: This subcomponent framework supports the procurement unit of any organization. This is used in purchasing the ICT devices and helps in checking the greenness availability or the green features of the manufactured equipment. The paper suggests that there should be specified standards while buying/procuring the ICT equipment and university systems should follow this rigorous process to ensure the green standards. Consequently, to purchase IT products/computers different green parameters like reduction of power consumption, recycling provisions & standards, reusability provisions & standards and refurbishing provisions & standards need to be considered. Also, rate of Co2 emission, products life span, products usage matrices, effects on environmental and amount of power needed to run the device are required to be checked. In normal practices the HEIs prepare the list of equipment such as what to be purchased and then select IT supplier based on their international green product certificate i.e. which products have green feature like Green & ISO standards. The buyer checks the greenness and benchmarking and then orders accordingly.

4.2.1.2 Green design framework: This subcomponent framework supports the data center design team of any organization. Designing the green ICT center is the process of green modeling and designing of IT resources, architectural layout and entire infrastructure by considering the energy efficiency and environmental sustainability. The Green ICT center design is critical issue and this subcomponent of the framework specifies the policy which focuses mainly on two green parameters such as selection of site/physical location and ICT center topology layout. Environment with rich of renewable energy sources like wind power is preferably advised for green ICT center. The cool and dry places like hill stations are preferably recommended locations so as to power consumption for cooling can be minimized. This framework suggests the salient artifacts of data center heights, non-heat conductor materials, auto exhaust, auto switching, auto diming and many.

4.2.1.3 Green usage framework: This subcomponent framework supports the usage team for smart and green usage in any organization. The level of awareness of the students and staffs was assessed about the need for green computing systems and practice and how they can adopt and contribute as change agent by reducing the power consumption such as number of items on their start up menus, screen color, screen intensity, screen background, multitasking, auto hibernating and algorithmic prioritizing etc. These issues are considered in awareness like green screen brightness setting, shutdown of computers when not in use, avoid screen saver, shutdown non-critical workloads, make sleep mode and server migration with Dynamic Voltage Frequency Scaling (DVFS).

4.2.1.4 Green printing practice framework: In higher educational institutions (HEIs) ICT center devices consume quite a huge amount of energy by printing and this green printing practices parameter should be reflected and practiced in the Institutions. Such measures should be considered to minimize or adopting substitute of printing. I) Framing the Rules and guidelines or adopting the rules and guidelines so as to share and or work on the same document at the same time using cloud based shareable platforms like Google doc in drive. This will minimize printing and re-printing. II) Framing Rules and guidelines or adopting so that numerous people meetings could be scheduled using E platforms like G. Meet, Zoom, and MS Team etc. III) Framing Rules and guidelines or adopting so that numerous people can use Emails and share disks to substitute printing; hence printing should be done only when it is absolutely necessary using recycled and light weight papers. IV) Rules and guidelines can be framed or adopted so as to use Projectors with soft copies of documents. These can be sent to members instead of printed documents during meetings, though this may

seem more expensive initially but over time the positive effects will be visible. V) Rules and guidelines can be framed for encouraging students and staff to print on both sides of the paper. VI) Rules and guidelines can be framed for replacing single device with multifunctional devices and thus save cost of purchasing and maintaining multiple devices as well as make printing and photocopying more efficient by reducing the energy they consume. VII) Rules and guidelines can be framed or adopted so that purchasing process can consider the energy efficient devices that meet the energy standards specified by energy star. VIII) Rules and guidelines can be framed or adopted for turning off machines when not in use and most importantly turning off the control switch to these devices at the end of every day work, weekends and holidays can also reduce power consumption.

4.2.2.5 Green disposal (reduce, reuse& refurbish and recycle): The green disposal of obsolete ICT equipment framework is embedded with the concept of reduction, reuse & refurbishing, and recycles which have proven to yield many benefits in both environmental and socio-economic space.

- **Reducing**: The specific rules and guidelines should be framed or adopted in the organizations for significantly reducing the power consumption during ICT usage. This can be voluntary or mandatory both.
- **Reusing:** The specific rules and guidelines should be framed or adopted in the organizations so that the old computers/devices can be manifested in many ways such as reselling or donating. The key concept with respect to reuse is to meet the user's needs with existing ICT equipment, while extending that ICT equipment life span in the universities. Based on this inference the framework is an effective approach to develop the reuse strategy or policy for ICT devices that confirm prolonged use of a computer system significantly contributes to the reduction of negative environmental effects in the universities.
- **Refurbishing:** The framework provides specific rules and guidelines that should be customized in the organizations. The ICT equipment can be manifested in ways: by up-grading existing systems of old computer systems. In this strategy of ICT equipment framework, old computers/hardware part can be reconditioned or replaced or refurbished at the refurbishing center for prolonging the device utilization. Old equipment can be restored in order to maintain its functions; it also can be upgraded for obtaining new serviceableness in refurbishing center that can be motivated by lower cost of refurbished equipment and energy efficiency too. Based on this implication the framework is an effective approach to develop the refurbish strategy or policy for ICT devices that confirm to prolonged use of computer systems/ devices. This significantly contributes to reduce e-waste and provide a cost-effective alternative of refurbished ICT equipment in the universities.
- **Recycling:** This is the process where used materials are turned into new products (not necessarily the same original ones) so as to minimize environmental impacts such as underground leaching, emission of greenhouse gases through burning the e wastes and

to promote resource conservation. The Re-cycling centers are required to be re-designed and upgraded so as to follow and maintain the green standards of the world consortiums. These standards can be adopted in higher educational institutions (HEIs). Based on such observations, and recommendations, the proposed framework can be made as an effective approach for greening the recycling strategy of ICT equipment. These practices are integrated with the newly proposed framework that leads to reduce power consumption of ICT products and maximize re-use of materials and minimize the expenditures for the processing.

4.3 Framework Simulation Experiment Using Cloud Sim

4.3.2 Cloud-Sim Toolkit

Cloud simulation is the toolkit (library) usually used for simulation of cloud computing environment so as to imitate the real-world scenarios in the labs. Cloud applications have different types of configurations and deployment requirements based on the research objectives. The main purpose of the CloudSim is to provide a simulation framework that permits modeling, simulation, experimentation of emerging cloud computing infrastructure and application services.

4.3.3 The Experimentation Steps

In this experiment, each scenario has a number of experiments that vary based on the value settings of the key parameters, hosts, VMs and Cloudlets (i.e. user application over virtual desktops in CloudSim environment). The characteristics of these three parameters were kept as the typical values already set in CloudSim as it has already been experimented and validated by Calheiroset.al to quantify CloudSim efficiency in simulating Cloud Computing environments [15]. In these scenarios, the experiments are done with 10 hosts, 20 Virtual Machines (VMs), and 20 Cloudlets as the default and the minimum values, and afterwards they are incremented to represent the higher scales of an ICT data center for each succeeding experiment.

4.3.3.5 Power Aware Mechanism

One of the objectives of this research study was to validate the framework results through stakeholder's inputs and simulated prototype. Hence the goal of this experiment was to measure and evaluate energy consumption in ICT center equipment while the number of resources and services increased. Deployment of DVFS mechanism can contribute on the way to reduce the energy consumption and it was then analyzed with respect to non-deployment. The values were set to the initial default value 10 hosts, 20 VMs and 20 Cloudlets as stated above in CloudSim and doubled, recorded and then analyzed for variations in energy consumption in KWh. The experiment based on Energy consumption value with DVFS enabled technique shown in Figure 4. Table 1 showed the result of our experimental values from experiment1 to experiment 10 respectively.

Table 1 Experiment values of power aware (DVFS Enabled with VM migration) mechanism

	Run 1	Run 2	Run 3	Run 4	Mean Value
Experiment 1	0.302	0.301	0.293	0.302	0.30
Experiment 2	0.605	0.592	0.602	0.602	0.60
Experiment 3	1.216	1.228	1.217	1.184	1.21
Experiment 4	2.546	2.522	2.510	2.498	2.52
Experiment 5	5.045	5.021	5.012	5.054	5.03
Experiment 6	10.133	10.097	10.122	10.072	10.12
Experiment 7	20.332	20.284	20.318	20.305	20.32
Experiment 8	40.633	40.599	40.693	40.705	40.66
Experiment 9	81.218	81.21	80.219	80.218	80.72
Experiment 10	121.753	121.749	121.760	121.760	121.76

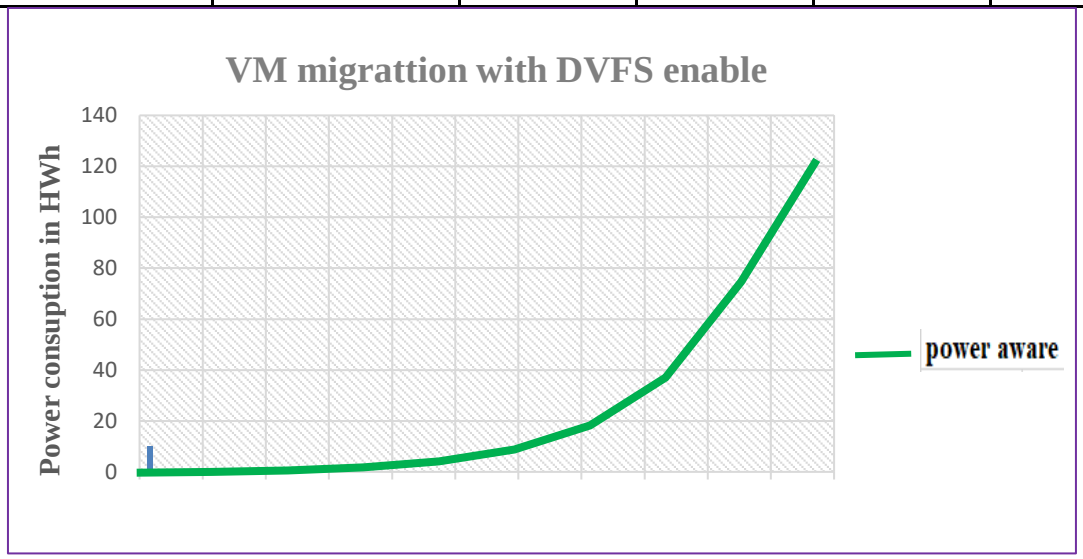

Figure 4: Energy consumption value for each experiment of power aware mechanism

4.3.3.6 Non power Aware Mechanism

The goal of this experiment is to evaluate how energy consumption value increased in the green ICT center that does not use energy reduction mechanism i.e. VM migration without DVFS enabled in compared to the green ICT center that uses energy reduction mechanism like DVFS enabled with VM migration. Increasing the number of virtual machines and services, it also increases the level of energy consumption. The values were set to the initial default value 10 hosts, 20 VMs and 20 Cloudlets as stated above in CloudSim and doubled, recorded and then analyzed for variations in energy consumption in KWh. The experiment based on Energy consumption value without any power aware mechanism enabled shown in Figure 5. Table 2 showed that the non-power aware result of experiment1 to experiment 10 respectively.

Table 2: Experiment values of non-power aware mechanism

	Run 1	Run 2	Run 3	Run 4	Mean Value
Experiment 1	1.087	1.084	1.055	1.087	1.08
Experiment 2	2.178	2.131	2.167	2.167	2.16
Experiment 3	4.378	4.421	4.381	4.262	4.36
Experiment 4	9.166	9.079	9.036	8.993	9.07
Experiment 5	18.162	18.076	18.044	18.194	18.12
Experiment 6	36.479	36.35	36.439	36.259	36.38
Experiment 7	73.195	73.022	73.145	73.098	73.12
Experiment 8	146.279	146.156	146.495	146.538	146.37
Experiment 9	292.385	292.356	288.789	288.785	290.58
Experiment 10	438.311	438.296	438.336	438.336	438.32

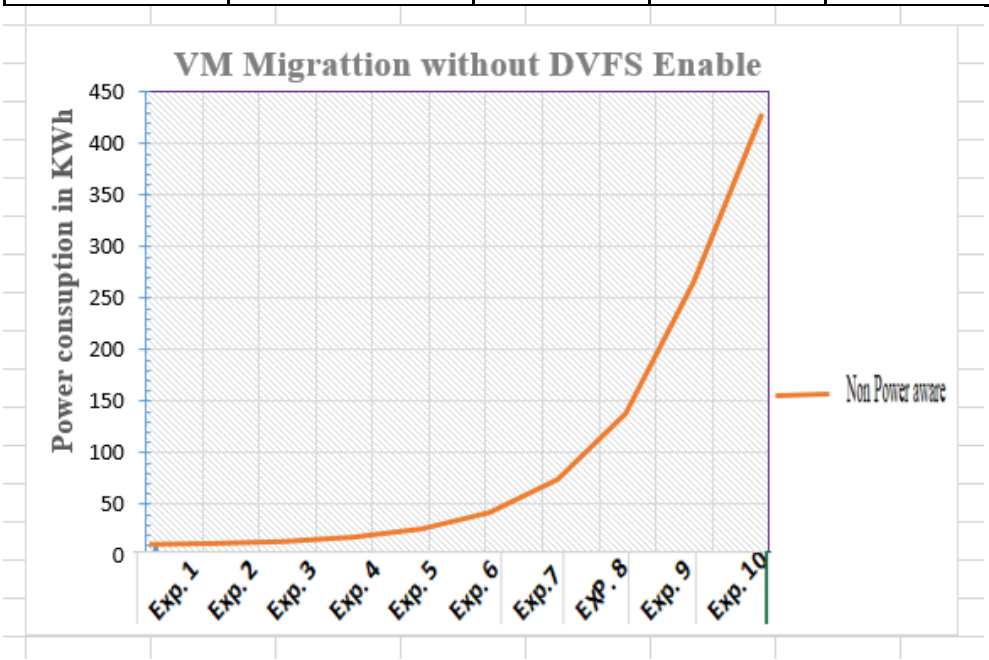

Figure 5: Energy consumption value for each experiment of non-power aware mechanism

Consequently based on the experiment it can be decided that as the resource and services get increased the energy consumption also increase doubling the previous one.

4.3.4 Analysis of the Experimental Results

The two experimental scenarios and deployment of DVFS with VM migration was run and the resulted the total energy consumption 121.76 kWh and shown in Figure 4 and without VM migration deployment of DVFS the total energy consumption was 438.32 kWh in which the result of simulation was shown in Figure 5. Thus, in terms of the parameter settings of this scenario, experiment 1 has the minimum values of 10 hosts, 20 VMs, and 20 Cloudlets, and experiment 10 has the maximum values of 5120 hosts, 10240 VMs, and 10240 Cloudlets.

From the results collected and calculated, Figure 6 produced to explain the difference between the two scenarios based on the mean values of the energy consumption metric in kWh

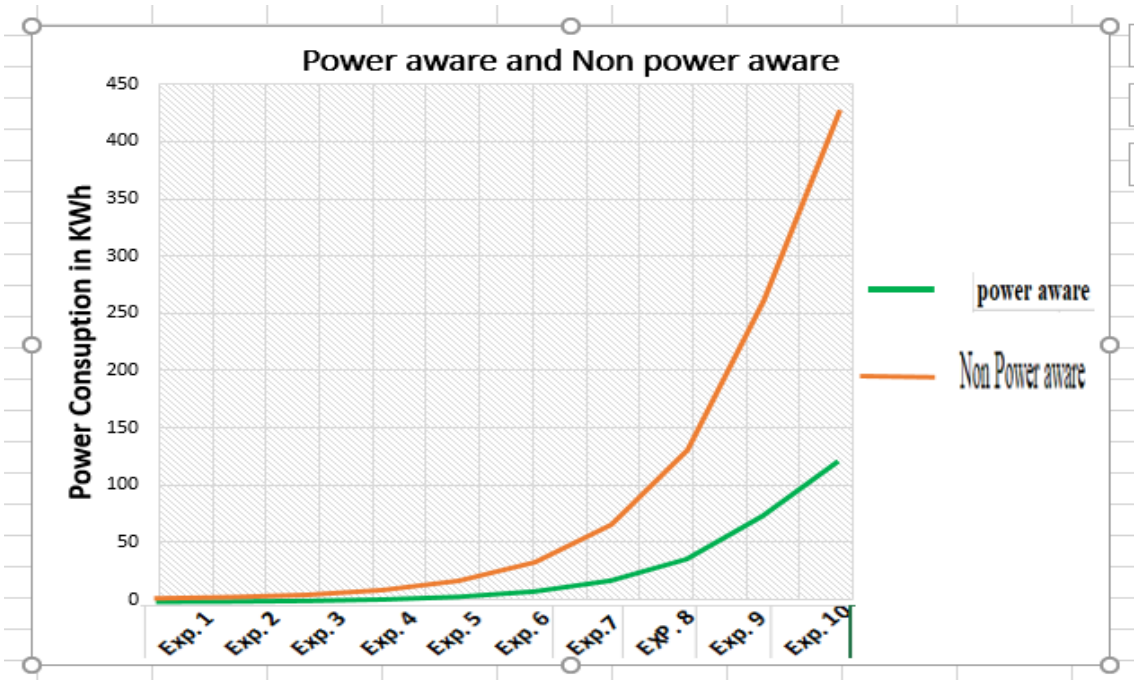

Figure 6: Comparison between experiment of Power Aware and Non power aware mechanism

Consequently, the results of the experiments clarified that; deploying DVFS with VM migration mechanisms can improve the eco-efficiency of a data centers. Based on the scenarios from 1 to 10, a ICT center with the deployment of DVFS with VM migration mechanism can consume significantly less energy than a ICT center with non-deployment of a power aware. This shows that how effectively the DVFS and VM migration mechanism can be designed for dynamically controlling the input voltage and clock frequency of a CPU to decrease the power consumption and the the VM migration technique based on the host CPU utilization.

4.3.5 Simulation Results

The simulation of the aforementioned configuration of ICT data center where hosts, virtual machines and cloudlets on the Eclipse IDE (for Java Developers) for a non-power aware ICT center provides the total energy consumption i.e., 438.32 kWh. In this the result of the simulation are presented in Figure 5. The simulation was done for the same configuration of ICT data center as well which implemented DVFS with VM migration, and hence the total energy consumption was found 121.76 kWh. This result is presented in Figure 4. Thus, the overall energy consumption of the ICT data center equipment was decreased by 95% for the given configuration of the ICT center when DVFS technique was applied with VM migration mechanism. Hence, DVFS along with VM migration is proved as an energy saving technique. It is used to reduce the power consumption by the hosts. This can be done by turning off the hosts that have utilization below predefined value (underutilized) and migrating the VMs

from the selected hosts based on utilization threshold (0.8) which is described above. This technique is proved as an efficient technique to reduce the power consumption of the ICT center devices, as it reduces the energy consumption by nearly 95% which leads to lower greenhouse footprints. Therefore, this experimental analysis using DVFS with VM migration can be a great contribution to reduce energy consumption at ICT data centers and also can reduce the Co2 emission significantly. This experiential analysis was done in reference to selected universities such as AMU, WSU and WCU ICT data centers, and a significant amount of energy saving was observed and ensured. In order to save environment and its effect on human life, this research can be used as a new knowledge contribution to green ICT centers so that the effect of ICT equipment over humans and the environment can be minimized.

5. Conclusion & Contributions

Green ICT is an evolving approach towards environment protection and sustainability of ICTs. The ICTs in future will consist of systems and practices to achieve corporate social responsibility by minimizing carbon footprint, managing ICT waste and conserving energy. This leads to lowering carbon dioxide emissions and supports environment sustainability. Based on the data collected and analyzed for issues and challenges using survey, interview and observation, the researcher's come up with green ICT framework for Ethiopian HEIs. The green ICT systems, frameworks and practices have contributed to make processes easier, faster and efficient for contributing to the environmental problems, through greenhouse gas emissions from the use of ICT equipment. The aim of this research paper was to reduce power consumption, apply refurbish, reuse and recycle practices for ICT equipment's a case study of selected institutions like Arba Minch University (AMU), Woliate Sodo University (WSU) and Wachemo University (WCU) located in Ethiopia. This was done with green factors deliberation and selecting a most suitable framework that can confirm Green ICT usage and advance the organization's ICT usage one step towards green products and services. The newly proposed framework i.e., a final contribution of the research is found to be a future road map for the adoption of green ICT for significantly reduced energy consumption, reuse and refurbish and recycle of the ICT equipment's and systems. It can help as judgment provision for the ICT directorate, ICT experts and users in selected educational institutions for choosing the most possible Green ICT i.e. next generation ICT centers. Energy efficiency should be the future indicator for sustainable development and this research could be able to play a new knowledge based promoter role towards green ICT in the universities.

As an important contribution, this research paper analyzed the current status and usage of ICTs and practices in Ethiopian HEIs. The study selected three main universities as sampling sites for primary data collection, and case observation. Later the green ICT framework is designed and proposed for reducing, reusing, refurbishing and recycling the ICT equipment. The experimental analysis done in simulated environment using dynamic voltage and frequency scaling technique (DVFS) with VM migration. The simulated results found that the energy consumption of the ICT center is approximately decreased by 95 % for the given

configuration of the ICT center equipment. This is claimed as a main contribution to reduce energy consumption, and minimize environmental impacts in the selected university ICT centers. This research is considered to be used as a baseline for designing the future generation data centers i.e. green data centers and their policy making in the developing countries like Ethiopia where the thought and concept of green computing and ICTs are in its infancy stage. This research can be an important help in aligning their ICTs and data centers comparable with global standards and practices.

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