# Minimizing Electronic Waste using Infrastructure as a Service

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**ABSTRACT**

E waste management is one of the main issues faced by the IT industry. E waste management consists of both less production of e waste and the recycling of the produced ones. Accumulation of e- waste can lead to resource shortage and environmental pollution. Moreover it also makes sustainable development hard and the idea of greener IT industry impossible. The recycling of e waste also helps in lowering the cost of manufacture of products. Along with the current methods for recycling of the e waste produced, the rising trend of cloud computing can be used for e waste management. Infrastructure as a service helps in reducing the use of hardware involved in both the front and back end of the industries, considerably. This paper analyses about the various e waste produced, its recycle and how Infrastructure as a Service can be used for the reduction of hardware.

## 1. INTRODUCTION

The most important and vulnerable component in computer system is a data centre. It is a warehouse for the storage, management, and distribution of data. It acts as a server where the greater part of storage and enterprise servers are operated and managed. When the computer systems, mechanical, lighting and electrical systems are designed for maximum energy efficiency and minimum environmental impact, it becomes the green data centre. It consists of advanced technologies such as e-waste recycling, sustainable landscaping, infrastructures management, energy consumption management, etc. It provides more computing and storage capabilities for less power utilization, lowers operational expenditure by aligning power consumption with workload requirements etc. One of the most important tribulations faced by the present world is the lack of proper e waste management. E waste includes all worn electronics which are destined for reclaim, resale, salvage, recycling, or disposal. Numerous of these products can be reused, refurbished or recycled in an environmentally sound manner so that they are less dangerous to the ecosystem and that the natural resources can be conserved. For efficient recycling of e-waste, the stake holders and companies producing the electronic equipments should take the responsibility and accept the e-waste of their own consumers. Along with that the public should be made aware of the rising crisis. Fig 1 gives a rough idea of E-waste produced.

**Fig 1: E-waste**

## 2. BASIC CONCEPTS

### 2.1. Electronic Waste

The e waste contains many lethal elements like lead & cadmium such as in cadmium batteries, cathode ray tubes with lead oxide & barium, brominated flame retardants which are used on printed circuit boards, cables and plastic casing; poly vinyl chloride (PVC) coated copper cables and plastic computer casings that discharge highly toxic dioxins& furans when burnt to obtain valuable metals. Mercury in flat screens, mercury switches, poly chlorinated biphenyl's (PCB's) present in older transformers, capacitors etc, also contribute to e waste production. The current method to reduce environmental hazard is hardware recycling which is based on the e-waste collection, dismantling and recovery of valuable components manually and final processing for metal

recovery through various metallurgical process. This can help in the management of e-waste to certain extend but does not solve the problem of e waste completely.
E-waste consists of more than 92% retrievable and reusable components, of which some are exceedingly precious and limited. Approximately, 50 million tons of e waste consists of 15 million tons of steel, 4 million tons of aluminium, 6 million tons of copper over & above glass, plastic, silver, gold, palladium, platinum, iridium etc. Because of high recycling costs in developed nations, 80% of e-scrap goes in land fill, in spite of being so resource rich. And, the developing nations regrettably do not deploy environment friendly practices. As a result, both the sets of countries are equally spoiling the environment and creating environmental pollution.
Computers contains lots of useful parts and modules that can be recycled, reused and re-purposed, that it's a disgrace to merely throw them away. PC fans make great air filters, mother boards can become jewellery, hard drive platters skilfully turn into clocks and power supplies, and c.d. drives become domestic secret safes and roulette wheels.

## 2.2. Recycling of e waste.

E waste management can be done by proper control over the materials used. The e waste produced can be recovered on-site, or through inter industry trade. Establishing material purchase review and control procedures, in order to keep track of the materials used, and also the inventory tracking system can aid minimizing the production of e waste. By the reduction of materials used the e waste production also reduces. In earlier times the computers used to occupy a room full of space. But by the advancement of technologies, the size of the computers reduced from room size to desk tops. Now a day, the size has been reduced to mere palmtops, fitpc2s, etc. When the size of such electronic devices decreases the amount of raw materials needed for their production is reduced, and thus the resources can be conserved. Likewise when the hardware size decreases, the amount of e waste created and disposed also decreases.
Procedures should necessitate that all materials be approved prior to purchase. By reducing both the quantity of hazardous materials used in the process and the amount of excess raw materials in stock, the quantity of waste generated can be reduced. Usage of raw materials carefully and ordering only the needed quantity of materials for production can reduce the adversity of e waste recycling. This also helps in lowering the production cost of devices, since the raw materials used are waste, resources can be acquired at a much lower cost than fresh resources.
Moreover improved operating and maintenance procedure, thereby increasing the efficiency of the existing production equipment, can also help in improving the efficiency of production process. Instituting standard operation procedures can optimize the use of raw materials in the manufacturing process and also can reduce the potential for materials to be lost through drips, leaks and spills. A strict maintenance course, which stresses corrective maintenance, can reduce waste generation caused by equipment failure.
Along with the hardware recycling techniques for e-waste management, we can also use cloud computing for the reduction of e waste production. When the amount of hardware produced decreases, the need for their recycling also lessens. Thus by using cloud computing we can reduce the production of hardware components.

## 2.3. Cloud computing.

A technology that uses the internet and central remote servers to uphold data and applications are called cloud computing. This is a mode of computing that is dynamically scalable through virtualized resources granted as a service over the internet. There are many different types of cloud computing options, with variations in security, back up, control, compliances and quality of service that must be thoroughly evaluated, to assure their use does not place the organization at risk. Cloud computing allows consumers and businesses to use applications without actual installation and access their personal files at any computer with internet access. This is one of the main advantage of cloud computing. The Fig. 3 shows how several computers placed at different locations can access a cloud. The cloud consists of several cloud providers like Amazon, Elastic Hosts, Google applications, etc. They provide the clients with their requirements. Here all the clients share the same cloud but each user has an impression of their own private hardware.
One of the themes within cloud computing is the disaggregation of hardware and software. Here the user of the software and the implementer of the software may not bear any relationship to each other. Amid this disaggregation, another thought arising from cloud computing is the idea of commoditization of computation. Exploiting the efficiency of a compute cloud at the node, rack and facility level is the key source of business value and a chief design consideration.

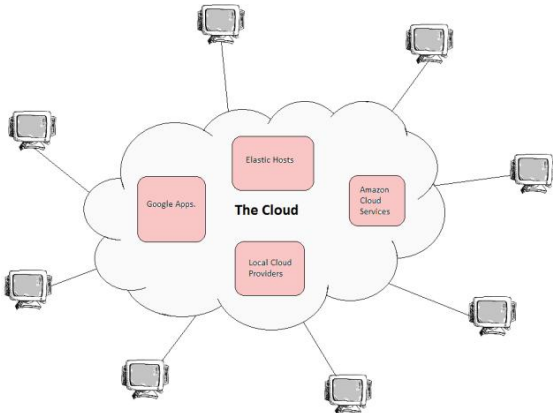


**Fig3: Cloud Computing.**

Cloud computing is typically classified in two ways i.e. by the location of the cloud computing and by the type of services offered. Further in the location of the clouds, it is divided as public, private, hybrid and community clouds. In Public cloud the computing infrastructure is hosted by the cloud vendor at their location. A public cloud sells services to anyone on the Internet. The customer has no visibility and control over where the computing infrastructure is hosted. The computing infrastructure is shared between any organizations.

In Private cloud, the computing infrastructure is dedicated to a particular organization and not shared with other organizations. It is highly scalable and flexible administered virtualized hosting solution permitting single physical servers to be partitioned into multiple autonomous virtual machines, each with its own operating system and set of applications to fulfil your needs. Private clouds are more expensive and more secure when compared to public clouds. In hybrid clouds, organizations could host vital applications on private clouds and those applications with comparatively less security concerns on the public cloud. Thus the hybrid cloud is the usage of both private and public clouds together. Community cloud includes the sharing of computing infrastructure among organizations of the same community.

Based upon service provided, clouds are classified as, Infrastructure as a Service(IaaS), Platform as a Service(PaaS) and Software as a Service(SaaS). Infrastructure as a Service involves presenting hardware related services with the principles of cloud computing. These could include some kind of storage services, like database or disk storage, or virtual servers. Infrastructure as a Service provides virtual server instance API to start, stop, access and configure their virtual servers and storage. In the endeavour, the cloud computing permits a company to pay for only as much as capacity as is needed, and bring more online as soon as needed. Because this pay-for-use model is similar to the way electricity, fuel and water are consumed; it is sometimes referred to as utility computing.Fig.3 shows the structure of IaaS which contain arrays of processors, memory peripherals, etc.

Platform as a Service (PaaS) involves presenting a development platform on the cloud. Platforms offered by different vendors are typically not compatible. Platform-as-a-service in the cloud is described as a set of software and product development tools hosted on the source's infrastructure. Applications are created on the provider's platform over the Internet by the developers. PaaS providers may use APIs, website portals or gateway software set up on the customer's computer. Developers require knowing that there are no standards for interoperability or data portability, currently in the cloud. Some providers will not let software created by their customers to be shifted off the provider's platform.Fig.2 shows the cloud stack. It depicts how the three layers of cloud are used by different users. The IaaS provides both the end users and application developers with some kind of storage space, virtual services, etc. The application developers use it to develop new platforms for the end users to run their applications. The end users can use the storage space directly or use the platforms provided, for their requirements.

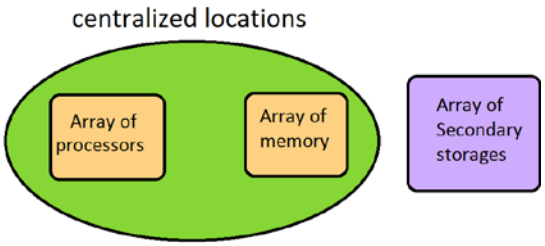


**Fig3: IaaS Structure.**

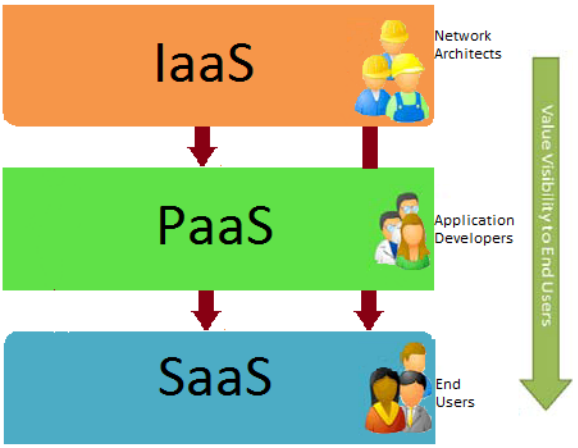


**Fig 2: Cloud Stack.**

Software as a service (SaaS) includes a complete software offering on the cloud. Users can use a software application hosted by the cloud vendor on rental basis. In the software-as-a-service cloud model, the vendor provisions the hardware infrastructure, the software product and communicates with the user through a front-end portal. SaaS is perceived as a very broad market; services can be anything from Web-based email to inventory control and database processing. Because the service provider hosts both the application and the data, the end user is free to use the service from anywhere.

## 3. E WASTE AND IAAS.

In hardware as a service otherwise called Infrastructure as a service (Iaas), a product is offered through the internet to a client, as an on-demand service delivers hardware such as servers, network tools, memory, CPUs, and disk space. Infrastructure-as-a-service (Iaas) is the delivery of computer infrastructure, typically a virtualised platform environment, such as a service. Rather than purchasing servers, software, data centre space or network equipment, clients instead buy those resources as a fully outsourced service. The service is characteristically billed on a utility computing basis and quantity of resources consumed, and therefore the cost, will naturally reflect the level of activity.

The concept of website hosting resembles the idea of Iaas. Customers are buying physical space on the company's servers for their web files to reside, when they pay the companies to host their website. Using the Internet clients can add, remove, or modify those files just as one would if that server was in their office - except in this occasion they are working with equipment that may be thousands of miles away. IaaS is a pay-as-you-go form which allows clients to scale up or down depending on their needs. When it comes to expensive hardware, clients can save a lot by buying only what they use.

From the perspective of IaaS, customers choose flexibility by attaining direct access to virtual machines (VMs) and by generating their own server and database instances as needed, and installing the required middleware and operating system resources. This provides a high extent of independence but increases

complexity. Infrastructure as a service seizes the conventional components of IT infrastructure, takes them off site, and presents them in one integrated, scalable package to companies who can supervise them through one management interface.
Infrastructure as a service results in IT provisions that simply conform to the changing requirements of a business. Because the infrastructure does not dwell on the premises, out-dated equipment, upgrades, and retrofits no longer take part in a role in the company's resolution to adopt new technology. The IaaS provider takes care of that smoothly, allowing the business to focus on its task.
Cost effectiveness augments the expediency of IaaS. Because the IaaS provider has enormous platforms segmented for each customer, the economies of scale are huge, providing considerable cost savings through efficiency. The need for each company to uphold its own infrastructure is eradicated through IaaS. The influence of IaaS brings the resources required to service government and enterprise deals to businesses of all size. IaaS improves reliability because service providers include skilled workers that ensure nearly constant uptime and state-of-the-art security measures.

## 3.1. Virtualization

Virtualization is the design of a virtual, rather than actual, version of something, for instance an operating system, a server, a storage device or network resources. The puddle of physical storage from various network storage devices into what appears to be a single storage device that is administered from a central console is storage virtualization. Storage virtualization is generally used in storage area networks.
Virtualization used as an alternative green technology, paved the way for infrastructure services to grow to be a reality. Virtualization eliminates form factor considerations from IT services since servers of every type and size can be configured to run on standard infrastructure. This implies that virtual servers can smoothly scale to larger or smaller capacities and exploit more or fewer resources according to the need. Resources such as processors, memory, software, firewalls, etc. can change in real time as the needs of the customer vary. In the meantime servers from different clients can reside on the same service provider platform, provided that for incredible efficiency in space, hardware, and manpower. In data centers, in a single machine, it makes sense to run multiple servers.These servers are mostly under-utilized, so combining them on one machine with a Virtual Machine for each of the existing machines enables fewer machines, less rack space etc. Thus the hardware content get reduced in significant amount.

Virtualization helps to optimize the hardware by allowing multiple processes to use the same hardware resources such as Virtual Machines, Virtual Routers.A virtual machine is a kind of computer application which is used to produce a virtual atmosphere, which is referred to as virtualization. Virtualization enables the user to perceive the infrastructure of a network through a method of aggregation. Virtualization can also be used to run multiple operating systems concurrently. The consumer can operate software placed on the computer platform, with the help of a virtual machine.

There are several types of virtual machines. Mostly, the term is used to imply to hardware virtual machine software, also known as a hypervisor or virtual machine monitor. This type of software helps in performing multiple identical executions on a single computer and in turn each of these executions drives an operating system. This allows multiple applications to be run on different operating systems. Using the hardware virtual machine software, the consumer has a apparently private machine with fully functional hardware that is separate from the other clients. Hardware virtual machine software also allows the consumers to boot and restart their machines swiftly, as chores like hardware initialization are not required. Fig. 4 shows how the different views are exported to the guest. It, means the view that should get exported to the guest should be of a complete computer system—with the processor, system peripherals, devices, buses, memory and so on.

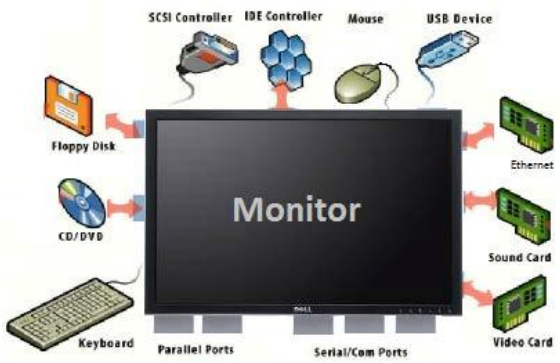


**Fig 4: Virtualization**

Implementing virtualization technique or by using virtual machines in Iaas, we can reduce the number of in-between hardware used by the consumers. IaaS providers present customers changing degrees of administrative liberty over their infrastructure through a unified Web portal. Infrastructure as a service keeps on growing in popularity because of its impact on the bottom line of all business. IaaS provides for the budgeting of hardware costs and the reduced down time of IaaS, its security and relevance in disaster recovery plans and its receptiveness signify that businesses gain through the availability of extra productive time.
Since environmental consciousness turns into a mandatory part of each business model, Iaas therefore assists the green initiative by addressing power utilization needs and by managing other matters such as the appropriate disposal of old hardware. Certain businesses may even qualify for tax breaks by using IaaS.

## 3.2. Reducing E waste using IaaS.

As Iaas deals about the on-demand service of hardware on a rental basis to clients as well the virtualization of existing hardware, it helps considerably in reducing the hardware used. Here the hardwares are replaced by

**Table 1:A comparative study of standalone and cloud systems.**

| Type of Sysytems | Cost | Security | Reliability | Flexibility and Access | Performance | Utilization of resources |
|---|---|---|---|---|---|---|
| Stand Alone Systems | High | High | 60% | Low | High | Low |
| Cloud | Less | Average | 90% | High | High | High |

online services and softwares. The growing demands of data and services can be handled by using Iaas without the actual introduction of a hardware device. Reducing the storage and network sprawl reduces the need to build more data centres. These IaaS solution give the customers the capability to deliver products and services in a fast as well as a convenient way, where ever and whenever they want, communicating on any device they choose. Table 1 shows a comparative study between the stand alone systems and cloud systems. It clearly shows the utilization of resources is high in cloud systems.

The IaaS helps the clients to use the resources available at different servers located at different geographical area, thus they have access to the various data and applications they need, without the actual presence of the hardware. Since the users do not have an actual hardware, they are also free from the stress of security of the data, which is the task of the data centres where the data is actually been stored by the user. The users can rely more on the data centres for the management of the data because, even if due to some errors or virus attacks the data gets lost, the data centres may have multiple copies of the particular data. Thus they can provide it to the user at his\her requirement. But that is not possible for a private hardware kept by the user. Once the data is lost, then it will be lost forever unless the user has another copy of the same. The data redundancy may seem to be an issue here, but since it ensures more reliability and safety to the data, that problem can be ignored.

Currently industries use their own set of hardware such as servers, storage devices, network equipment, etc for accomplishing the companies' tasks. Thus when each company use such lot of devices individually, the number of hardware used increases considerably. But if a single highly efficient data centre or server can provide the facility of storage, service, etc to several industries at a time, then the need for their own separate hardware is reduced. Here there is no need for the industries to buy expensive highly resourceful devices. The same works done by using large expensive front end devices can then be accomplished by using low cost, less efficient devices with internet access.

Workload from various systems when pooled together makes it possible to consolidate bigger sets of workload in a single platform than using different operating systems and devices. Virtualization of storage and servers provides companies with tools to address the under exploitation of resources and the poor economics of silo-based storage, as well as the flexibility to respond to shifting business needs.

In cloud computing, we are accessing the data stored in the datacentres in a rental basis. Likewise we can also use the hardware units in a rental basis. The companies will provide the hardware to the customers as in a pay-per-use basis and will take it back in case of any damage. Thus the deposition of e-waste can be reduced. The producer companies can use the parts of these components for the production of latest products by giving some alteration. This will avoid the utilization of new resources and the renewable elements can be preserved for the future. Along with the preservation of valuable components, the illegal handling of e-waste also can be prevented. Since the disposed electronics consists of precious as well as poisonous materials, if these components reach the wrong hands, they could be used for illicit purposes.

These methods also help service providers to bring in more profit. About one-third of corporate cloud computing users are stressing infrastructure as a service as they pursue a path toward higher profitability. By putting down the purchase of computing infrastructure out of the budget, managers not only recognize further profit, but the business enterprise benefits through a periodic predictable infrastructure rate set in the deal for IaaS. Also, the quantity of infrastructure required often oscillates for a company meaning that time of reduced resource utilization will cost less, while surges in utilization can directly scale to meet the need. Businesses save money and increase profit by restricting their expenditure on underutilized infrastructure while avoiding the costly moments when internal infrastructure basically cannot sustain.

## 3.3 IaaS Properties

### *3.3.1 Scalability and Elasticity-*

Amount of infrastructure resources needed could be dynamically increased or decreased. The system behaviour remains the same whether it is large scale or small scale. Large amount of resources establishment and organisation could be done in small period of time.

### *3.3.2 Availability and Reliability-*

Access to computational resources without hardware failure must be provided to the users. Along with this, users are able to retrieve data when required without any effects of natural disasters. Communication capability and capacity could be sustained without any problem of shortage of equipment.

### *3.3.3 Manageability and Interoperability-*

Clients are able to control the allocated virtualized infrastructure resources completely. The states of virtualized resources are under monitoring, the usages of the resources are recorded and the billing system converts this to user payment.

### *3.3.4 Performance and Optimization-*

Physical resources provided by the cloud forms a large resource pool which provisions high computing power through parallel processing. These resources are highly exploited amidst different users. Virtual infrastructure resources are dynamically organised to an enhanced deployment among physical resources.

### *3.3.5 Accessibility and Portability-*

The infrastructure resources could be managed by the users in an easy way without further hardware or software installation as well as it could be reallocated or reproduced conveniently.

## 4. CONCLUSION

From these, it can be concluded that, e waste management is one of the main problems faced by the IT industry. By using Infrastructure as a service, the e-waste can be managed by the reduction of hardware produced. When data can be handled without the actual introduction of devices, the need for more data centres also reduces. The cloud service, infrastructure as a service will give a more efficient way to manage e waste for both consumers and producers. The customers can easily update the new versions of systems in a rental basis rather than worrying about the disposal of the e wastes and the acquiring of new device. And in case of the producers, they can earn more profit. When hardware is given on a rental basis, the need for the more number of production decreases. Since recycling provides them with cheaper raw material, cost of production is reduced. And the less production of hardware by implementing Iaas reduces the need for recycling and conserves natural resources, thereby making IT more eco-friendly.

## 5.ACKNOWLEDGEMENT

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## 6. REFERENCES

[1]. Recycling from e waste to resources-Step solving the e waste problem.

[2]. Thrive Networks-Thrive Tech; Infrastructure as service; Software as a service.

[3]. Explaining Infrastructure as a Service (IaaS)- *Article by Bruce Tyson*. http://www.brighthub.com/environment/green-computing/articles/85165.aspx

[4]. Importance of recycling of e-waste- *B K Soni, Chairman, Eco Recycling Ltd, Mumbai, India.*

[5]. Environmentally sound options for e wastes management- *Ramachandra T .V, Saira Varghese K.* ewasteguide.info/node/219,ewasteguide.info/node/201

[6]. Cloud computing- a collection of working papers*; Thomas B Winans, John Seely Brown.*

[7]. The future of cloud computing-Opportunities for European cloud computing beyond 2010-*Lutz Schubert.*

[8]. Facts and Figures on E-Waste and Recycling- *Institute For Local Self Reliance, "Recycling Means Business," 1997.* [10].Virtualization-*LAD Enterprises.inc.*

[9]. Sungard availability service-Solutions/Cloud/ Iaas/Pages/ Infrastructure as a service(Iaas).aspx.

[10]. Best Management Practices For Electronic Waste- *Santa Clara County Department of Environmental Health San Jose, California.*

[11]. Identifying Barriers to Efficient Recovery and Sustainable End of Life Management of Electronic Waste by *Erinn G. Ryen, and Dr. Callie Babbitt, Rochester Institute of Technology (RIT).* [IEEE].

[12]. Types of cloud computing- *http://thecloudtutorial.com/cloudtypes.html*.

[13]. Infrastructure as a Service - IaaS: Cloud Computing posted by *Basant Narayan Singh.* http://www.techno-pulse.com/2010/04/infrastructure-as-service-iaas-cloud.html.

[14]. Leaseweb- *http://www.leaseweb.com/en/custom-solutions/private-cloud.*

[15].Cloud Computing: An Introduction. *http://www.explainingcomputers.com/cloud.html.*

[16]. Green Computing - New Horizon of Energy Efficiency and E-Waste Minimization – *World Perspective vis-à-vis Indian ScenarioSanghita Roy and Manigrib Bag.*

[17]. What is Virtualization- *http://www.wisegeek.com/what-is- a-virtual-machine.htm.*

[18].Virtual Data Center/IaaS- *http://www.cbts.cinbell.com/solutions/cloud-computing/virtual-datacenter*.

[19].Research on Innovative Information-Flow Management of E-Waste Recycling Network Based on Cloud Computing by *Kejing Zhang Ping Cang, JuttaGeldermann, Fugen Song*.[IEEE].