Exploring Practices to Utilize Information Technology Towards a Greener Environment, and Studying the Financial Implications of those Practices on Individuals and Corporations

بحث ممارسات تشغيل تقنية المعلومات بصورة أكثر استدامة للبيئة، ودراسة التبعات المالية لتلك الممارسات على الأفراد والمؤسسات

by

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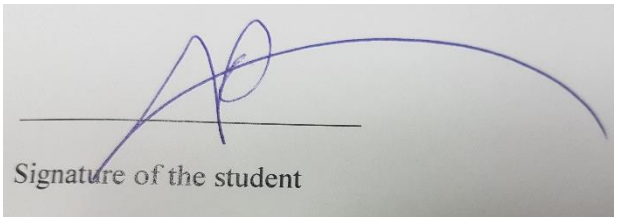

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Abstract

Green information technology practices refer to ones that have proven to be beneficial in protecting the environment. These approaches have been devised as a response to the continued environmental degradation realized due to the constant level of industrialization and usage of computing devices. Information technology hardware infrastructure consumes enormous amounts of power for running, cooling, and maintaining this equipment. Thus, there is a need for growth in green technology adoption.

Information technology practices discussed in this dissertation are server virtualization, cloud computing, business process automation, internet of things, green software engineering, and value engineering. Some of these practices provide real-time monitoring of environmental behaviour. Others directly establish proper resource management, leading to reduce power consumption and heat dissipation. The overall effect is that pollution is reduced significantly, in addition to a great value added to the users in terms of effort saving and financial cost.

The hypothesis that needs to be tested is that green information technology practices have a substantial benefit not only to the environment, but also to the society and the economy. If green technologies do not have a positive financial implication in reducing cost, individuals and corporations will be less likely to adopt them. This dissertation will give a brief history of the interaction between technology and the environment and critically analyse the concept of green technology. Data will be collected from literature, case studies, and conducted interviews with professionals in the environmental and information technology fields. Also, this dissertation will find whether green information technology practices add enough value to the environment and the society compared to their financial cost.

الخلاصة

لقد أثبتت الممارسات الخضراء لتقنية المعلومات جدوتها في التخفيف من التراجع البيئي. وقد وُضعت هذه النُّهُج كاستجابة للتدهور البيئي المستمر الذي حصل نتيجة الاستخدام المفرط لأجهزة الحوسبة. تستهلك البنية التحتية لأجهزة تقنية المعلومات قدرًا هائلًا من الطاقة لتشغيلها وتبريدها والحفاظ على استمراريتها. وبالتالي، تصبح الحاجة إلى زيادة الاعتماد على التقنيات الخضراء في جميع مجالات تقنية المعلومات أمرًا مُلحًّا.

تناقش هذه الورقة الممارسات الخضراء في تقنية المعلومات في المجالات التالية: الخوادم الافتراضية، والحوسبة السحابية، وأتمتة العمليات الإدارية، وإنترنت الأشياء، والهندسة الخضراء للبرمجيات، والهندسة القيمية. توفر بعض هذه الممارسات رصدًا آنيًّا للسلوك البيئي، بينما يساهم البعض الآخر بشكل مباشر في إدارة استهلاك الموارد، مما يؤدي إلى تقليلِ استهلاكِ الطاقة وانبعاثِ الحرارة، حيث يكون تكون المحصلة الختامية لهذه الممارسات الحدَّ من التلوث البيئي بدرجة كبيرة، وإضافةَ قيمة كبيرة للمستخدمين من حيث توفير الجهد والتكلفة المادية.

الفرضية المُختبرة في هذه الورقة هي أن الممارسات الخضراء لتقنية المعلومات تعود بنفع كبير ليس فقط على البيئة، بل وكذلك على المجتمع والاقتصاد، فإن لم تكن للتقنيات الخضراء آثارٌ إيجابيةٌ في خفض التكاليف المالية، فسيقل اهتمام الأفراد والشركات باعتمادها وتبنيها. سوف تعطي هذه الورقة تاريخًا موجزًا للتفاعل بين التقنية والبيئة، وستقوم بتحليل مفهوم التقنيات الخضراء. سيتم جمع البيانات من متون البحوث العلمية، ودراسات الأحوال، وإجراء مقابلات مع مهنيين متخصصين في مجالي البيئة وتقنية المعلومات. وأخيرًا، سوف تستخلص هذه الورقة ما إذا كانت الممارسات الخضراء لتقنية المعلومات تضيف قيمة كافية للبيئة والمجتمع مقارنة بتكلفتها المالية.

Dedication

To those who intend good to humanity.

Acknowledgement

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Table of Contents

List of Figures

List of Tables

List of Equations

1 Introduction

1.1 Background Information

The natural environment is composed of the non-living, as well as, the living beings. It includes all the interactions between all the living beings, weather, climate, and the natural resources that affect the economic activities as well as the survival of human beings (Bergstrom and Randall, 2016). Technology, on the other hand, is the collection of techniques, skills, and the methods that are used in the provision of services as well as the production of goods. Developing the basic tools is the simplest form of technology dating back to the discovery of fire and the invention of the wheel (McClellan III and Dorn, 2015). Yet, technology has both negative and positive effects. The main positive effect of technology is improving the humans' quality of life. However, some of the negative effects include loss of social norms and the environmental degradation.

Technology must claim its favour of saving the resources which would no more be wasted. A significant product that can be replaced by information technology is paper. The paper demand of the world in 2016 can be calculated to be about 407 million tons (Statista, 2016). Figure 1 below shows a trend in global consumption of papers and cardboard from 2006 to 2015. It can be observed that the total volume of papers consumed worldwide has been rising over the last one decade.

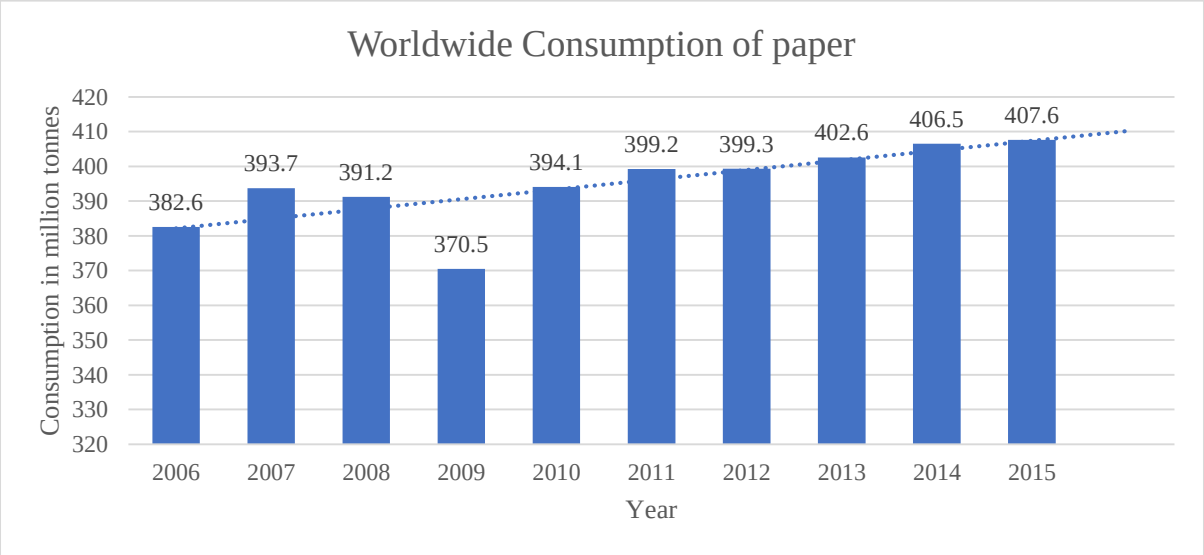

Figure 1: Worldwide Consumption of Papers (Statista, 2016)

The volume of water and amount of energy consumed in the paper industry have been increasing over the last few years owing to the high demand for paper products in households, offices and other factories that use paper resources. Accordingly, the paper industry is one of the greatest consumers of energy accompanied by the use of more water during the cooling process of the plant. Figure 2 shows statistics about the worldwide energy consumption in paper production. Each ton of paper consumes a minimum of 7 Megawatt-hours of power (Low-Tech Magazine, 2016) and 10 tons of water (Paper On Web, 2016). Assuming a 10% paper usage reduction by information technology, it can be estimated that about 284.9 million Megawatt-hours of energy and 410 million tons of water can be saved annually.

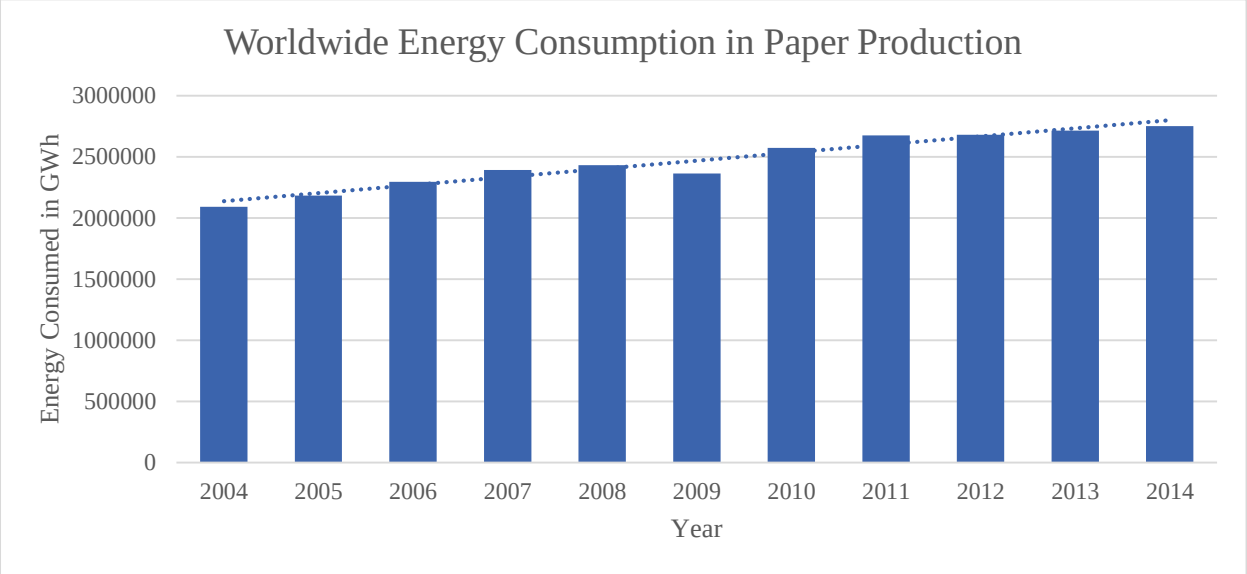

Figure 2: Worldwide Energy Consumption in Paper Production (International Energy Agency, 2016)

Speaking of energy, it is also worth mentioning that the worldwide consumption of electric power has always been increasing for many decades. Figure 3 below shows the overall consumption of electric power since 1990 till 2016. The information technology industry must claim a portion of that since the typical major costs of operating data centres is power, water, and hardware replacements (Masanet et al., 2013). Several strategies are being used to reduce power consumption and improve the microeconomics of data centres. The key question for businesses is how much extra resources are needed and how much extra returns are realized. For companies, periodic purchase of computers, software, and workforce to support the business is a burden. Therefore, conventional IT practices should go through value engineering evaluation to ensure having a greener effect (Bai and Sarkis, 2013).

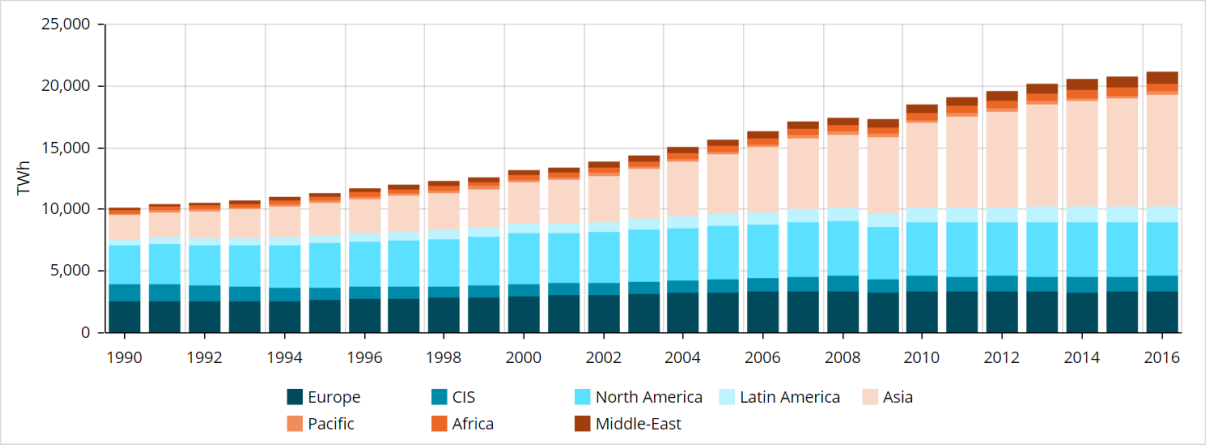

Figure 3: Worldwide consumption of electric power (Global Energy Statistical Yearbook, 2017)

1.2 How Technology Affects Mankind

Technology is an important driving force behind the growth of today's Global Economy. From mobile phones to cars to factories to home appliances, billions of electronic devices are poised to meet the information and communication needs of the entire globe. People can compute weather for agriculture, check safety from storms, find routes using GPS, assist industrial machines in controlling production lines, and the list goes on.

Earlier, these tasks were accomplished using physical visits of experts and writing on paper. Producing paper is not only destroying our oxygen-giving-forests, but also consuming huge amounts of power and water. Today, writing paper is being replaced by magnetic media that can be reused several times (Pöyry Global, 2015). Although this seems like a big move towards saving trees, and hence the environment, technology still degrades the environment in various ways. For example, manufacturing technology products deplete natural resources and emits pollutants that detriment the environment (Intergovernmental Panel on Climate Change, 2014).

It is essential to consider optimizing power requirements for operating technology. While petrol economy is not expected to last even few centuries, the agricultural economy is already around for thousands of years, and without renaissance, it would have dominated the world's economies indefinitely. So, is silicon-based electronics also a transient phenomenon like petrol? Petrol would be replaced by biofuels and solar energy in the future, yet, the problems of technology are solved by better technologies, and there are no such immediate radical solutions to replace electronics. Photonics is still a dream. However, there are several

incremental means that can increase material and power efficiencies over the life cycle of electronic components.

Environmental degradation is a reality that we have to deal with for ensuring a better future for the upcoming generations. Technology is advancing at an alarming rate. While this is a good indicator for enhancing the quality of life of mankind, we cannot overlook the environmental issues that are continually being experienced on a daily basis. Environmental pollution from information technology resources starts right from when the technological devices are manufactured, throughout their use and all the way up to their disposal (Unhelkar, 2010). It is thus safe to state that the more devices produced, the more pollution is caused. Bearing this in mind, the development of green information technology is paramount (Unhelkar, 2010).

Businesses are gradually becoming dependent on information technology irrespective of their sizes and nature of operation (Jennings, 2014). According to Masanet et al. (2013), there is a huge dependency on information technology in providing business applications for different purposes. The power load in utilizing business software can be carried on either server in data centres run by IT specialists, or on local client PCs used directly by end-users. This variation in hosting hardware depends on the type of applications used by the business (Masanet et al., 2013). The Table 1 below represents how much employees depend on server-based applications in their daily work for some application types. In comparison, Table 2 shows how much employees rely on local PCs in running other types of applications. It can be noticed that both hosting practices are significant to keep the business operation running and that most employees need to rely on both types of applications hosting (Masanet et al., 2013).

Table 1: Estimated server-based software use by firm size (Masanet et al., 2013)

	Percent of application users using server-based software by firm size		
Software application	<100 employees	100-499 employees	500+ employees
Email	100%	100%	100%
Productivity software	50%	90%	100%
CRM software	50%	75%	100%

Table 2: Estimated percent of computer users using business software applications (Masanet et al., 2013)

Occupation	Percent of computer-based workers using software application		
	Word processing	Internet and email	Spreadsheets
Management, business, science, and arts occupations	77%	100%	71%
Service occupations	55%	100%	49%
Sales and office occupations	64%	100%	62%
Natural resources, construction, and maintenance occupations	51%	100%	53%
Production, transportation, and material moving occupations	41%	100%	50%

The more the number of IT resources in a company, the more the possibility of increased pollution. According to Masanet et al. (2013), it was reported by Lawrence Berkeley National Laboratory and Northwestern University that 86% of the primary energy generated from natural resources to supply the IT sector in the U.S. is consumed in data centres alone. It is important to realize that all machines emit heat and waste energy. In addition, over-running these technological devices in idle time reduces their expected lifetime, thus requiring replacement. Information technology firms need to invest more efforts in adopting green technology approaches (Masanet et al., 2013). They will not only result in reducing the negative impact of technological advancements on the environment, but will also help humanity lead healthier lives.

1.3 Defining Green Technology

Green technology is a wide concept where electronic devices, design models, and engineering practices are expected to monitor and conserve the natural resources in the environment to control behaviour that negatively impacts the environment (Lindahl et al., 2014, pp.288-296). Green technology incorporates many different disciplines, including renewable energy generation, energy conservation, water purification, sewage treatment, air purification, and waste management.

Green information technology adoption refers to the responsible use of computers and other technological resources (Dastbaz et al., 2015). It encompasses environment-friendly hardware design, smart software design, and responsible practices that aim at reducing power consumption (Dastbaz et al., 2015). It is also highly dependent on social awareness and government policies. In the current era, information technology has spread all over the world. With the numerous IT resources that continue to be obtained by organizations and individuals daily, the possibility of wastage of these resources is increasing.

There are various methods which have been identified in the reduction of pollution and a subsequent increase in efficiency of operations. In this research, we will discuss these approaches based on related literature. We will also analyse case studies, and conduct interviews with professionals who work in fields that study and utilize these approaches. These approaches include Server Virtualization, Cloud Computing, Business Process Automation through software, Internet of Things, and Green Software Engineering.

Server Virtualization helps reduce the number of servers utilized and optimize the remaining ones so that they can carry out multiple functions simultaneously (Jenkin et al., 2011, pp.17-40). Cloud Computing is another method that involves the transfer and storage of files, documents, and software from the physical server on local premises to host servers on the internet (Liu-Mei et al., 2013, p.7275). Documents can then be accessed on the cloud, reducing the physical space required to store these files locally. Automating business processes using software have also been embraced to help reduce paperwork thus reduce the excess need to have trees cut down (Torrecilla-Salinas et al., 2015, pp.124-144). These systems have the capabilities to automatically record data in servers reducing the need of having physical paperwork. Internet of things is an emerging technology that enables devices to communicate real-time data. IoT is very useful in monitoring different environmental behaviour in real-time, thus, allowing to take immediate actions when necessary. Green Software Engineering is also a successful approach to be adopted towards a greener planet. It is a strategic management approach that employs financial and technological schemes to reduce environmental degradation (Penzenstadler et al. 2014, pp.40-47).

1.4 Financial Cost of Information Technology

The perspective of business stakeholders could be different. Returns from IT have to be justified every quarter. For an organization, IT requires continuous capital replenishment to avoid obsolescence, which is a financial challenge. According to Penzenstadler (2015, pp. 157-186), there is a high need to get stakeholders to perceive the importance of environmental sustainability in addition to assuring an organizational profit. Efforts are underway to modify both software and hardware to get improved operational efficiencies at the lowest possible costs.

Value Engineering is a major process that must be practised before any project is undertaken. It is highly correlated with green software engineering, especially when it comes to analysing gathered requirements. The value engineering process involves running an

organized approach, which helps achieve project functionality at the lowest costs (Bai and Sarkis, 2013). The analysis of value engineering can assist in determining if projects provide enough positive value to the environment as well as to individuals and corporations in return for their financial cost.

1.5 Summarizing the Objectives of this dissertation

This dissertation aims at reviewing how simple techniques can render information technology environmentally benign. The basic concept of these techniques is to reduce the required resources to perform different tasks. Hence, power consumed and heat dissipated could be reduced, less hardware could be more utilized, and the dependence on a variety of devices could be optimized. Those techniques can also enable users to monitor environmental activities in real-time, hence enabling them to perform accurate data analysis and forecasting to take the most suitable actions to mitigate problems. We will also discuss the financial implications of those techniques. Value engineering principles should determine whether it is possible for those methods to actually reduce costs on both individuals and corporations and whether these cost reductions produce gain to the environment. Data will be collected from related literature, case studies, and conducted interviews with professionals in related fields. Afterwards, this data will be analysed, conclusions will be formed, and recommendations will be suggested.

2 Literature Review

2.1 Environment

The environment is the occurrence of both the living and the non-living beings naturally. Their major concept that distinguishes the natural environment is the existence of the ecological units that function naturally without the interaction of the human civilization, in addition to the physical phenomena and the physical resources (Bergstrom and Randall, 2016).

Other than the natural environment, there is the built environment, which includes areas that have been significantly transformed by mankind in terms of agricultural or urban settings. The natural environment is negatively affected in various ways by human activities, and that leads to environmental degradation. An example of the most common signs of environmental degradation is global warming which is caused by the emissions of greenhouse gases including carbon dioxide (Intergovernmental Panel on Climate Change, 2014).

2.2 Technology

Technology can be defined as the artificial skill of providing services and producing goods. Technology first began in the prehistoric era of time through the discovery of fire, and later in the Neolithic period through the invention of the wheel (McClellan III and Dorn, 2015). New technology kept evolving over the ages till it reached to what we have today. Despite having remarkable positive effects on the quality of life of mankind, technology has significant negative effects on the environment. Most technological processes produce remnant substances that pollute the environment, including the greenhouse gases (Fingas, 2016).

During the year 2014, the electricity used in the US accounted for the emission of about 31% of the greenhouse gases emitted from the US during that year. (Howarth, 2014, pp.47-60). Due to the increase in the wide range of technologies, as well as the increase in electricity consumption, countries need to prepare for a higher energy demand. This trend indicates that there is a need for the world economies to turn to the utilization of renewable energy sources. The US renewable energy supply has increased to about 70% from the year 2005 to 2014. However, it only represents 15% of the total electricity consumed (Pazheri et al., 2014). The adoption of the wind and solar energy has helped reduce the emissions. However, new technologies should be adopted to offer opportunities for energy efficiency.

2.3 Environmental Technology

Environmental technology goes by many different names, like clean technology or green technology. It is simply the application of technology to model, monitor and conserve the environment (Rexhäuser and Rammer, 2014, pp.145-167). Green Technology also describes the development and production of sustainable energy technologies, including bioreactors, wind turbines, and photovoltaic panels. It also describes systems such as the internet of things and its applications in various energy, air, and water monitoring efforts that seek to preserve the environmental resources (Lindahl et al., 2014, pp.288-296).

2.3.1 Server Virtualization

Virtualization is a technological approach that allows system administrators to create multiple instances of an operating system or an application from a single physical hardware. A virtualized environment comprises of a hypervisor, virtual machines (VMs), applications, storage, and servers, all running on the same physical hardware. The process of virtualization evolved when mainframe administrators understood the need to reduce wasting processing power (Han et al., 2015, pp.90-97). They do this by making it possible to fit multiple computing activities into a limited number of servers that are highly utilized, hence, minimizing hardware idle time. A lot of operating costs are reduced as both the overall required physical space and maintenance costs of servers are substantially reduced (Issac and Israr, 2014).

Virtualization is not only limited to operating systems, but it can also take the forms of the server, desktop, application, memory, data, storage, and network virtualization (Brettel et al., 2014). The actual hardware on which the virtualization activity takes place is referred to as a host. On the other hand, the virtualized instances of the operating systems and their applications are often referred to as guests. When creating multiple guest instances on one host, the operation works perfectly well because the guest applications do not necessarily require the full resources of the underlying host hardware (Brettel et al., 2014). Configuring a virtualized application to not fully require the underlying hardware grants the administrator greater control and flexibility through reduced dependence on the primary server.

Companies like General Electric (GE), IBM, and Bell Labs have pioneered the server virtualization technology in the early 1960s (Bashe et al., 1986, and Rosenblum, 2004, p.34). In fact, IBM's products during that time seemed to appeal much to the scientific community. Additionally, the first generation of computers suffered a lot of deficits including slow speed of processing as well as the lack of the ability to multitask. That prompted IBM to begin

research on the design of the mainframe to bring about compatibility and a simultaneous system (Bashe et al., 1986). Massachusetts Institute of Technology was then initiating research in computing and mathematics since they needed a time-sharing computer system which IBM was not willing to produce as it perceived no demand. However, GE took up the opportunity and supplied the institution with the system mentioned above. IBM noticed that it had lost a serious opportunity and committed to designing and developing a commercial mainframe computer system which became the first operating system to support virtualization (Fanning & Cannon, 2015). Virtual machines became more preferred as the developments went on as compared to time-sharing OSs as they offered higher efficiency in sharing system resources. Additionally, later innovations made mainframes more secure and reliable to avoid crashing the entire system (Fanning & Cannon, 2015).

The technology of virtualization has undergone a lot of evolution to become what it is known to be today. VMs were utilized in wide applications during the 1970s with multiple innovations being made to give rise to prominent servicers designed with the X86 architecture, which is a design for computer instruction sets that allows more simultaneous processes in 32-bit memory capacity, as compared to the earlier 16-bit memory capacity. Additional improvements to X86 resulted in the birth of VMWare in 1999 (Rosenblum, 2004, p.34). Improvements did not stop at VMWare but have continued all through with a remarkable collaboration between Intel and AMD in 2006 to support hardware design (Rosenblum, 2004, p.34).

This technology provides the greatest opportunity for cost saving because it allows access to the server by many users simultaneously with low crashing probability. It moreover has inbuilt high availability capability hence enabling to allow for the highest level of server utilization. Virtualization provides consumers with unmatched reliability, excellent security, and very low downtime for the fastest and easiest management of organizational operations. With virtualization, the operating system becomes independent, facilitating fast data recovery, live backup, easy migration of data, and reduced hardware (Brettel et al., 2014).

Other advantages of this technology include the possibility of running multiple operating systems simultaneously with the ease of using multicore processors, hence facilitating cost savings (Fanning & Cannon, 2015). However, virtualization suffers from a few disadvantages including, hardware compatibility issues, and requiring specific system administration skills (Han et al., 2015, pp.90-97). The technology has also some negative

impact on the environment since it causes several OS to run on the same physical hardware hence affecting power efficiency of the host which may result in the consumption of too much energy from a single server. Yet, it helps reduce the number of used servers, resulting in less total energy consumed, and hence, a greater positive effect on the environment.

2.3.2 Cloud Computing

Cloud computing refers to the technology of delivering computing services such as data processing, software, networking, and database storage over the internet. Therefore, it is possible for multiple users to access the system at the same time without interfering with another's work. The idea of cloud computing is very similar to Server Virtualization where different users can access the same pool of resources. The main difference is that server virtualization provides these resources within a Local Area Network (LAN), while cloud computing does it over the internet. Several companies providing cloud services charge customers based on the amount of usage like any other utility corporation (Klinkowski & Walkowiak, 2013, pp.44-51). The concept of cloud computing did not just begin in the 21st century, but its origin can be traced back to the 1950s when mainframe computing was the order of the day. During this period, it was costly to afford a mainframe computer for every employee, and therefore employees would access a central computing system through a dumb terminal. Additionally, data storage needs were not as high as it became in today's businesses, so it made economic sense to provide a shared access for this resource (Hashem et al. 2015, pp.98-115).

The idea of providing computing resources via a universal network found its foundation in the 1960s. Within the same period, McCarthy John, a computer scientist, made a proposition for computation services to be delivered as a public commodity (Khalid, 2010, pp. 278-281). Later in 1999, the journey of computing crossed a significant milestone with the invention of salesforce.com through which enterprise applications were provided in the form of Software as a Service (SaaS). The design gave way for other corporations to venture into providing mainstream software services (Khalid, 2010, pp. 278-281). Later in 2006, Amazon started contributing to the ongoing innovation and improvement of cloud computing by launching Amazon Mechanical Turk and Amazon Web Services offering various cloud-based resources such as human intelligence, data computation, and storage services (Khalid, 2010, pp. 278-281). Then, Amazon continued its efforts by launching EC2 (Elastic Compute) cloud; a commercial service meant to allow individuals and small firms to rent space to run their

applications (Khalid, 2010, pp. 278-281). Today's cloud computing infrastructure is facilitated and kept up to speed with the growth and development of virtualization technology. Later in 2011, Google has also entered the cloud service providing market by launching Google Cloud Platform (GCP). GCP is a cloud service that provides networking, data hosting, storage and Big Data, computing engines, Machine Learning services, and Internet of Things device management (Google Inc 2017).

Cloud computing, as a transformative technological innovation, delivers plenty of advantages and benefits to both big and small corporations. Users of the technology gain ease of access to resources, flexible scalability, efficiency, and security. Cloud computing resources can be virtually accessed from anywhere provided it is Internet-connected. That also saves organizations the need to deploy and maintain their own hardware. Also, service providers can provide regular updates to their hardware, so customer system admins don't have to worry about the hassle updating their systems. Moreover, universal accessibility implies that people can collaborate globally and push forward the agenda of technological innovations (Gupta et al., 2013, pp.861-874). Cloud service managers ensure that the underlying infrastructure offers an enabling environment for businesses to take forward their strategic value. Providing shared web services improves business mobility since employees can now access applications and data no matter where they may be situated (Gupta et al., 2013, pp.861-874).

Power Usage Effectiveness (PUE) is a term used to measure the wasted power in a data centre. As shown in Equation 1, PUE is a formula indicating the ratio of energy consumed by a data centre facility over to the energy that was delivered to IT computing equipment (Google Inc., 2017). For instance, if a PUE for a data centre is 1.7, it means that the total power consumed by the datacentre facility is 70% more than the power delivered to the IT computing equipment. The ideal PUE ratio is 1.0, which means that all power supplied to the data centre is delivered to the computing hardware. However, that's almost impossible as there must be power consumed for cooling and distributing energy to the facility.

Equation 1: Power Usage Effectiveness (Google Inc., 2017)

$$PUE = \frac{Electric\ power\ to\ cool\ \&\ distribute\ power\ to\ IT\ equipment}{Electric\ power\ delivered\ to\ IT\ equipment}$$

PUE ratio changes due to many variables including the size of the datacentre. Table 3 shows the estimated PUE of a data centre based on its size; obviously, large cloud datacentres have the best power saving among all other sizes. Despite all the mentioned advantages of cloud computing, including flexible scalability, efficiency, security, and now power saving, the vast majority of data centres are server closets and server rooms serving single organizations (Masanet et al., 2013). The problem with server closets, server rooms, and localized datacentres is that they have high values of PUE, meaning, they consume a lot of extra power for cooling compared to cloud data centres (Masanet et al., 2013). Figure 4 shows the distribution of data centres in the U.S. in 2013 based on their size and the type of hosted applications.

Table 3: Estimated Power Usage Effectiveness of a Datacentre Based on its Size (Masanet et al., 2013)

Data center type	Average PUE
Server closet	2.5
Server room	2.1
Localized DC	2
Mid-tier DC	2
Enterprise-class	1.5
Cloud	1.1

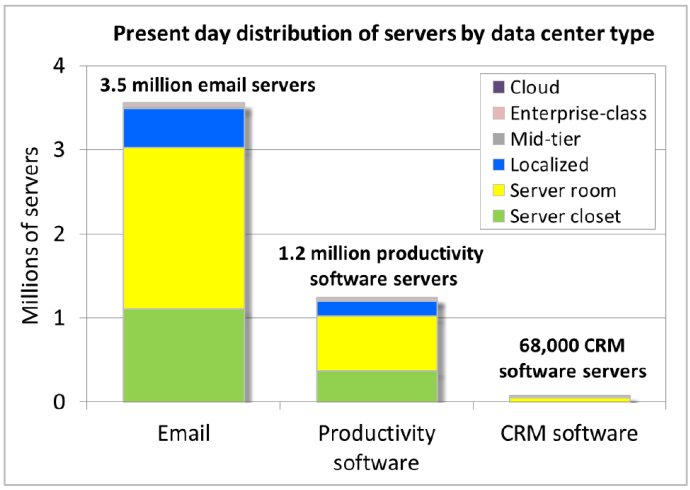

Figure 4: Datacentre Distribution in the U.S. in 2013 Based on Datacentre Size and Type of Hosted Application (Masanet et al., 2013)

Cloud resources are flexible in the sense that they can scale infrastructure on demand to support inconsistent workloads in addition to offering enough storage space when needed (Bojanova, Zhang & Voas, 2013). Efficiency in cloud computing comes from the fact that users get computing power only based on their demand, yielding to minimum power waste. Consumption of energy has been a major concern for many businesses owing to the impact it has on the environment in addition to its financial cost (Klinkowski & Walkowiak, 2013, pp.44-51). However, cloud computing provides the environment with an appropriate solution by saving excess energy consumed. If businesses were to install their own storage, energy consumption would increase. So, shared data storage providers save on energy usage as they consume only when data is required. Those advantages ensure a high saving on equipment on the business hence efficient and cost-effective business operation (Klinkowski & Walkowiak, 2013, pp.44-51).

2.3.3 Business Process Automation

Business process automation (BPA) through computer software is a direct consequence of an organization's desire to become more efficient, transparent, and compliant with quality standards. When automation is introduced in a corporation, it ensures that employees perform their duties appropriately, increasing their productivity and hence profitability. A fully automated system needs to be one with processes that are defined and consistent with best practices in the industry. Furthermore, the process should be structured and streamlined to minimize if not even eliminates repetitive errors. Automating business process through software has a primary purpose of making organizational operations cost-effective, transparent, error-proof, and streamlined (Unterberger & Singer, 2017).

According to Askarany, D. (2015) and Zynda M.R. (2013, pp.68-72), software business process automation started with the evolution and use of spreadsheets which began as early as the 70s when two MIT students, Daniel Bricklin and Bob Frankston, realized the need of having a visual computer that would allow people to carry out mathematical and accounting operations. Their invention came to be known as VisiCalc in 1978. In the beginning, Bricklin alone could not develop VisiCalc to market standards, therefore, teamed up with Frankston who expanded the spreadsheet. However, in 1979, the two were joined by a Byte Magazine editor, Daniel Flystra, with whom they launched VisiCorp which embarked on large-scale production of the technology. The business was an instant success, especially in fast-growing electronic spreadsheet market. In the 80s, VisiCorp shareholders were reluctant to giving Mitch Kapor, the head of development at VisiCorp at that time, a window of opportunity to develop Lotus that later rapidly emerged to become the standard spreadsheet (Askarany, 2015, and Zynda, 2013, pp.68-72).

Mitch used the money gained from selling his shares in VisiCorp to fund a start-up in 1982 called Lotus 1-2-3 Development Corporation alongside with Sachs Jonathan (Zynda, 2013, pp.68-72). Lotus 1-2-3 became the most innovative and creative tool for presenting and packaging complex calculations. Lotus, as a spreadsheet vendor, introduced cell naming, ranges and spreadsheet macros (Zynda, 2013, pp.68-72). Before embarking on solo production, Lotus 1-2-3 had been offered to VisiCorp, but its management rejected it on account of limited application. The company continued to grow significantly in revenues and employees under the watch of Mitch. It also acquired VisiCorp and discontinued VisiCalc for it had been declared no longer in use (Zynda, 2013, pp.68-72).

In the process of automating businesses, other technologies such Enterprise Resource Planning (ERP) software evolved. ERP software integrates the major organizational functions such as accounting, customer relationship, human resources, and inventory management into a single system for efficient business management (Ram et al., 2014, pp.663-675). ERP software finds their strength on the ability to provide a database that supports numerous functions desired by various units in the firm. For instance, marketing, accounting, and human resources can rely entirely on a single information resource to make streamlined decisions (Tarhini et al., 2015, p.25). ERP systems moreover save the employees much time instead of maintaining separate manual information resources for compiling reports. With such unification and automation in place, it is possible for staff to pull their reports from a single resource that is fast, reliable, and easily accessible (Bernroider, Wong & Lai 2014).

ERP software delivers value to businesses in their daily operations by breaking down information communication challenges between departments. Organizational activities benefit from ultimate visibility into all the important data in all units so that senior leadership can take appropriate actions (Nwankpa, 2015, pp.335-344). It is also possible to experience consistent and automatic workflow from department to department hence facilitating quicker completion of tasks through reliable process transactions, which obviously lead to higher profitability and cost saving (Tarhini et al., 2015, p.25).

ERP software has a direct positive impact on the environment. When an organization highly relies on digital media to perform their transactions, paperwork will be significantly decreased. Hence, this will contribute to reducing cutting trees, and will contribute to saving energy and water consumed in the production of writing paper (Pöyry Global, 2015). Also, integrating and automating processes enables the management of an industry to track the flow of waste from production to consumption. It is hence possible and easy to manage how waste products are disposed of reducing the causes of global warming and other devastating effects on the surrounding (Pöyry Global, 2015). However, automating processes using information technology and ERP software will result in consuming more energy on the servers, hence producing more heat emissions. Therefore, it is important here to consider more information technology techniques that optimize power consumption on servers, so the net value gained by the environment is positive (Rexhäuser and Rammer, 2014, pp.145-167).

2.3.4 Internet of things

Internet of Things (IoT), refers to the inter-networking process of various electronic devices. These devices are generally referred to as smart devices, and this is mainly because they are embedded capabilities to collect and communicate data. Across various network infrastructures, IoT devices can be accessed and controlled remotely (Rose et al., 2015, pp.1-50). The term Internet of Things was first used in 1999 by the British technologist Ashton Kevin (Rose et al., 2015, pp.1-50). Ashton used it to describe a situation where various objects and tools in everyday life could be connected to the internet using communication devices. Ashton used the term to describe the power of connecting Radio Frequency Identification (RFID) tags to the internet to count goods in a supply-chain process without human effort. Today, the term is used to refer to the computing capability and internet connectivity extended to a variety of everyday items (Rose et al., 2015, pp.1-50).

The term IoT is relatively new. However, the concept of combining several devices or networks to control devices has been around for quite some time. For example, in the early 1970s, systems that could remotely monitor electric meters on grids were already in use, and in the late 1990s, developments in the wireless technology allowed establishing Machine to Machine (M2M) connection which was used to monitor various devices as well (Madakam et al., 2015, p.164).

There is no single universally accepted definition of the term. Various definitions have come up and have been used by different people to promote the view that they hold about IoT. Some of the definitions emphasize on the internet and the internet protocol, whereas, others do not. For example, according to the Internet Architectural Board, internet of things reflects a trend where many devices can utilize communication services that are offered by the Internet Protocol (IP) at the same time (Tschofenig et al., 2015). However, according to the International Telecommunications Union, the term Internet of Things refers to a universal infrastructure for the information society that enables different services to be interconnected either physically or virtually (Vermesan and Friess, 2014).

It can be acknowledged that IoT has become an important topic in the engineering circles and in the technology industry. It is incorporated in the industry of producing systems, networked products, and sensor devices. This technology takes advantage of the improvement

in computing power, network interconnections, and electronics miniaturization (Zanella et al., 2014, pp.22-32).

The large-scale implementation IoT promises to transform the various ways in which human beings live . Consumers are likely to benefit from the use of internet enabled appliances, energy management devices, and home automation components (Zanella et al., 2014, pp.22-32). Medical professionals are going to benefit from health monitoring devices, thus, transform the way healthcare services are being offered. The elderly and those with disabilities will benefit from these devices to improve their level of independence (Rose et al., 2015, pp.1-50). Smart cities which have automated sensors and intelligence traffic systems will not only help minimize congestion but also help with the conservation of energy (Zanella et al., 2014, pp.22-32). For those in the agricultural sector, IoT offers an opportunity to improve their production. IoT promises to also support environmental conservation through methods such as energy conservation and pollution detection. IoT can monitor energy consumption levels in a large number of machinery in a firm and can detect if a machine is consuming more than it should be. This data can be communicated in real-time and corrective actions can be taken quickly. Similarly, IoT can help conserve the environment through managing and optimizing water consumption in agriculture (Atzori et al., 2014, pp.97-105).

2.3.5 Green Software Engineering & Value Engineering

Green Software Engineering is a management approach that applies financial and technological approaches to reduce environmental pollution (Penzenstadler et al., 2014, pp.40-47). It can be defined as the commercialization, design, and utilization of various processes and products that promote sustainability, reduce environmental pollution, and thus reduce the risks to the environment and human health (Penzenstadler et al., 2014, pp.40-47). Green engineering in general is based on a number of principles; these include minimizing the depletion of the earth's natural resources, preventing the wastage of resources and energy, conserving the natural ecosystem when protecting well-being, applying the concept of project life-cycle in every engineering activity, and ensuring that all the energy inputs and outputs are safe (García, 2014, pp.803-813). When it comes to software projects, Penzenstadler (2015, pp. 157-186) suggests that the green software engineering process starts from the very early stages of software projects, which is during requirements gathering, all the way to business analysis, software architecture, and even software testing. She also suggested that decisions made to

protect the environment and human health have the best impact and cost-effectiveness when applied in the early stages of a project or production process (Penzenstadler, 2014, pp. 44-53).

Green software engineering is closely tight with the concept of Value Engineering. Principles of value engineering are based on the cost-value analysis, which is a methodology that identifies expected benefit opposing to unnecessary costs (Miles, 2015). This approach involves deep analysis to identify the wanted value, and hence, designing the function that can achieve it. Also, the approach involves identifying unnecessary costs and making the decisions to eliminate them without disrupting the function. Value engineering can be represented in a simple ratio of function over cost (Miles, 2015), shown in Equation 2. If a project is to achieve a positive value, then the designed function should estimate higher than the cost, yielding a value of 1.0 or more. If the value ratio yields less than 1.0, it means that the project has endured unnecessary costs that didn't reflect in benefits. Thus, a successful project should achieve the maximum possible functionality with the minimum endured cost.

Equation 2: Concept of Value Engineering

$$Gained\ Value = \frac{Function}{Cost}$$

With the initiatives of some of the well-known worldwide movements for protecting the planet, including the World-Wide Fund for Nature (WWF), sustainability is gaining a significant importance. Other organizations such as the United Nations are trying their level best to influence the world powers to adopt green energy initiatives, thus, reduce energy consumption and reduce carbon footprint (Calero and Piattini, 2015).

In fact, technology plays a very important role in promoting innovation in both the developed and the developing countries. Yet, information and communication technology (ICT) has a negative effect on the environment. Thus, when pursuing sustainability, it should be taken into consideration how ICT can help organizations deal with the environmental issues instead of being responsible for serious environmental degradation. It is reported that the ICT sector contributes to about 3% of the global emission of carbon dioxide and about 10% of the total electricity being used in the European Union (Calero and Piattini, 2015). It is important to control the use of information and communication technology in order to reduce the effect it has on sustainability. Software technology is one way through which this can be achieved because software engineering has more downstream economic activities associated with it

compared to hardware engineering. In general terms, the initiatives to foster sustainability for the environment through ICT is referred to as Green Software Engineering.

Sustainability is a term that is used to refer to the capacity of anything lasting for a long period of time. Thus, environmental sustainability ensures that the environment is given the opportunity to heal itself faster than it is destroyed through human actions. The scope of environmental sustainability through green software engineering is broad and is includes various sustainability levels. In respect to software sustainability, the sustainability initiatives need to be applied when implementing software systems, software products, data centres, and web applications (Calero and Piattini, 2015). One of the best ways of achieving software sustainability is by optimizing the resources needed to run these projects. It can be acknowledged that energy efficiency has only recently been taken into consideration in software engineering, thus, focusing on this holds great potential for the realization of sustainability.

3 Problem Definition

Environmental pollution as a result of electronic technology has and will continue affecting humanity. Information technology has led to increased environmental degradation. As much as the constant development in the information technology sector has continued to benefit humanity, the adverse effects have unfortunately been hard to ignore.

Paperwork is excessively used in many organizations. As papers consumption increases, more trees need to be cut. New software solutions are emerging every day. Many of these software solutions are relatively new, and they just started to mature up recently (Torrecilla-Salinas et al., 2015, pp.124-144). However, unfortunately, since most of the senior leadership workforces who work in organizations today are from older age groups, they tend to rely on traditional ways of processing and storing documents. There is a high resistance from the old generation employees to utilize automated systems in replacement to their paperwork.

Consumers use a lot of electronic devices and gadgets daily. All these devices require power to run, not to mention the power consumed by servers communicating with these devices. The infrastructure in datacentres contributes in 86% of the heat emissions caused by the information technology sector (Masanet et al., 2013), which is quite a significant amount of pollution.

Organizations are gradually embracing the use of computers and other technological devices in their operations. Data centres are being built by almost every company individually to run its internal applications. Yet, the way it is utilized is that a single server is limited to running certain applications only (Jenkin et al., 2011, pp.17-40). Servers are the most powerful computer components in any IT department, hence, the highest in electricity consumption. In most companies, different business operations require different servers. Hence, the more the operations, the more the required servers. In fact, one server can handle much more complex processing than what most typical business operation would require, and that means a server needs a lot of power just to boot and stay awake. Hence, if the server is to wake up just to run these small business operations, it will end up consuming a lot more power than needed. Scaling this problem to the many servers used by different business functions, they end up using a lot of electricity and generating a lot of heat.

Servers and computers will always need corresponding IT professionals and experts to maintain them and make sure they operate properly. This results in increased human resources

overhead. Physical space is also a major factor that must be considered. The servers and equipment take up a lot of space which ultimately results in an increase in other costs including space rent, maintenance, cooling, and electricity.

It cannot be disputed that most of the advancements made in technology come at a cost to the environment. For example, the tarmacked roads and the railways damage the natural habitats of various living organisms. Industrialization, on the other hand, has contributed to the pollution of air, land, water, and sound. Different types of pollution have negatively affected the environment, and that causes the environment to behave in unpredicted ways.

Therefore, the problem definition can be summarized in the following points:

1. Paper consumption is organizations is high, and paper production requires high consumption of water and energy
2. Servers in company-owned datacentres are under-utilized, hence, consuming extra power for cooling and maintaining, in addition to the overhead cost of physical space and manpower
3. Individuals are utilizing technology highly on the personal and industrial level. The high level of industrialization and technology utilization has caused direct damages to the environment, which causes a significant reduction in natural resources

4 Research Methodology

This dissertation has a defined research methodology. A research methodology is a logical sequence to connect collected data between the defined problem and the proposed solution. In this dissertation, three research methodologies have been used to collect and analyse data, which are related literature, related case studies, and semi-structured interviews with professionals in related fields. After analysing the data collected from those methods, it was found that some of them suggest answers and provide solutions to the defined problem. As the study will focus on testing the theory, these research approaches can be applied to achieve the objective of the investigation.

In the beginning of this research, data about worldwide energy consumption were introduced. This data reveals prominence facts that the consumption trend is going up. This data is used to indicate the need to identify some causes of this problem and suggest solutions to reduce their negative effects. Hence, this research tackles reducing power consumed by information technology related devices using the suggested solutions.

The objective of the research approach in this dissertation is to elaborate a holistic perception of the phenomenon at hand. As a result, data employed in the study is amorphous, but it becomes more involved as the research progresses. Qualitative research will permit the realization of research objectives and goals in determining the market trend regarding information technology currently available. Gathering data through multiple interviews supported by this technique will help acquire knowledge and reliable information from participants and respondents, hence reducing chances of receiving bias information associated with questionnaires.

4.1 Case Studies

4.1.1 Server Virtualization Case Study

Many companies have taken it upon themselves to try to protect the environment from further degradation. Businesses are therefore embracing server virtualization in order to add a positive value to the environment as well as to maximize their returns on investment (Unhelkar, 2010). The following is an example of an organization that has embraced server virtualization in its business leading to positive results on the environment and the business.

4.1.1.1 Cisco Study on Coca-Cola

Coca-Cola bottling company is a multimillion company that sells carbonated drinks worldwide. Based on a case study by Cisco (2011), according to Neel Dennie, a network and telecommunications specialist in Coca-Cola, the company had been faced with a server sprawl in their data centre that resulted to poor cooling of the servers and a subsequent outgrow of the power that was available. The heat that was produced was too much, and a decision was to be made to find a solution. The company has worked hand in hand with Cisco, the international networking hardware and telecommunication infrastructure company, in order to construct another data centre and consolidated the data from the previous servers. The 80 servers that were earlier used were reduced to four, with 20 virtual machines hosted on each one of the consolidated servers. The huge reduction in the number of servers has also lead to reducing the number of SAN storage devices used, less cable supply by 30% to 60%, in addition to less space occupation and less power supply requirements. Neel has confessed that since the shift, the company has realized a significant decrease in power consumption and heat emission. This has ultimately led to the company saving a lot of money that would have been used to cater for electricity hence resulting in a rise in the profit margin (Cisco, 2011).

4.1.2 Cloud Computing Case Studies

Cloud computing is a technology that claims to reduce environmental degradation as well as adding value to businesses and individuals. The main concern about cloud computing is the enormous amounts of energy and water consumed to cool and maintain its massive infrastructure. The case studies below have answers to this concern and show how cloud computing can actually be a benign green technology.

4.1.2.1 Cloud Computing Case Study: Google Cloud Efficiency

According to Datacentre Dynamics, "Google has one of the largest but also one of the greenest data centre infrastructures among the world's companies" (Sverdlik, 2012). With optimization techniques, Google data centres are designed to use 50% less energy than typical data centres; they build their own custom servers, use outside air for cooling, and even raise the data centre's temperature to 26.6°C to consume less energy (Google Inc., 2017).

Power Usage Effectiveness (PUE) is a formula indicating the ratio of energy consumed by a data centre compared to the energy that was actually delivered to computing equipment. This formula is presented earlier in this dissertation in Equation 1. For instance, if the PUE

ratio is 2.0, it means that the total energy consumed to run and cool the equipment is double the energy used in the actual computing and storing of data. However, if PUE is around 1.0, this means that almost all the energy is used for computing. Google has been tracking its PUE for years, and it has dropped significantly since they first started reporting it in 2008. Their trailing twelve-month PUE average across all Google data centres is 1.12 which makes them among the most efficient data centres in the world (Google Inc., 2017).

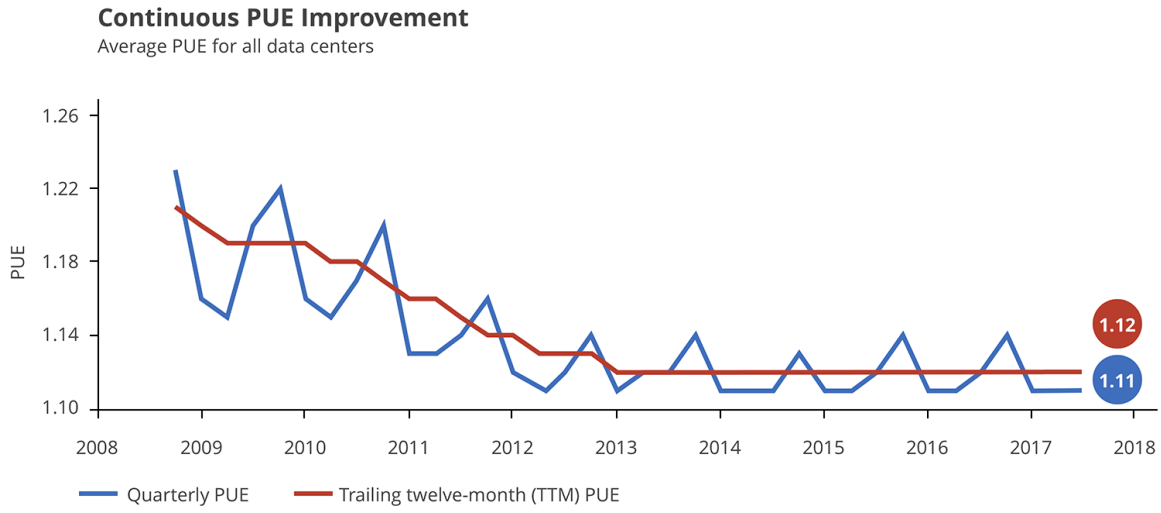

Figure 5: PUE data for all large-scale Google data centres (Google Inc., 2017)

When using Google's cloud products, like reading emails on Gmail or watching videos on YouTube, users interact with servers in data centres. These servers support multiple products at a time, and this is how the cloud concept works. By utilizing the full capacity of servers, they can do more functions with less energy consumption. The cloud offers a better distribution of resources among many users. This allows businesses to do more with less energy. According to Lawrence Berkeley National Laboratory, energy used by information technology in an organization can be reduced by 87% by moving data processing and storage to the cloud (Masanet et al., 2013). By changing their culture to embrace cloud technology, organizations can utilize technology more effectively and be more environmentally friendly. Related specifically to Google products, companies have reduced total office devices computing costs, energy consumption, and carbon emissions by 65% to 90% by switching to G Suite (Previously Google Apps) (Google Inc., 2017). Additionally, using Gmail as the

mailing service in a businesses can decrease the negative impact on the environment by around 68–87% compared to hosting email services on local servers (Google Inc., 2012).

4.1.2.2 IDG Study on Cloud Computing

Cloud computing has always been a topic of interest to most Information Technology environmentalist. According to a cloud computing survey that was undertaken by IDG Enterprise marketing in 2015, around 72% of 962 companies had at least one application in the cloud at the time (IDG Enterprise Marketing, 2015). The objective of the survey was to understand how different cloud service models are being used in different companies. These companies stated that cloud computing was easy, reliable, and cost-effective. They had every intention of increasing their presence on the cloud. Almost 56% of technologists were still trying to find out where cloud computing would be leveraged but were very optimistic about it. The survey has found that there is a rising investment by organizations in cloud technology. The main drive for that is the lower cost of cloud services for these organizations in comparison to building their own data centres. (IDG Enterprise Marketing, 2015).

4.1.3 Business Process Automation Case Studies

Automated software systems lead to minimize the necessity to use paper-related materials. This is because most papers are required for storing information hence for filing purposes. Systems that have internal saving functions do not require such material to be printed for record purposes. One of the most common examples for adopting automated systems is Enterprise Resource Planning (ERP) systems. Organizations utilize ERPs for converting their paperwork into electronic processes that provide better recording and tracking of data.

4.1.3.1 Implementing SAP in Rolls-Royce

Rolls-Royce were established in 1904 as a car manufacturing engineering firm. It has developed through the years and liquidated its shares in 1971. It has continued to develop and entering new marketplaces. It expanded later by acquiring different engineering firms including Northern Engineering Industries in 1989 and Allison Engine Company in 1995. Those expansions allowed the Rolls-Royce to improve its experience in the areas of industrial power and aerospace engines (Yusuf et al., 2004, pp.251-266). Rolls-Royce is known for its world-class products, and it has multiple facilities in 14 countries in the world. It also provides after-sales services maintenance and overhaul services and spare part distribution (Yusuf et al., 2004, pp.251-266).

Before its implementation of the ERP system, it had previously used over 1500 systems, and many of them were in-house. Those legacy systems latter proved to be expensive to operate, not to mention their support and maintenance. The company needed to perform fast and accurate operations on their data to enable them to take necessary business decision. However, those legacy systems were not fit to those requirements. They later adopted a corporate cost accounting (CCA) system that was used for monitoring financial transactions in inventory. The company had also different software systems for running different operations related to financial and procurement functions (Yusuf et al., 2004, pp.251-266). Rolls-Royce then adopted the SAP. At that time, different businesses highly recommended SAP for different engineering industries, including aerospace and defence. SAP system has helped them in generating business reports that provide accurate information to justify in business cases. (Yusuf et al., 2004, pp.251-266).

This system has helped them in dealing with the current demand of the market in the production of products faster and of higher quality. The processes have been streamlined and the amount of time consumed has reduced significantly. They were able to prepare and deliver orders to customers faster than ever, which obviously saved them a lot of time and effort, and enabled them to get more business deals. The other benefit is saving cost. Although implementing SAP required them to purchase extra servers, computing devices, and software licenses, it was about only a year of time till the system has finally stabilized, and employees got used to the new practices, and that was when IT was clearly saving a lot of cost on the company.

4.1.4 Internet of Things Case Studies

IoT can be utilized to save the environment in many ways. The case studies below focus on utilizing IoT in monitoring certain circumstances and communicating data about them in real time. Thus, correct decisions can be taken accurately and quickly.

4.1.4.1 The Fluvial Aquarium of Zaragoza

The Fluvial Aquarium of Zaragoza aquarium is the largest aquarium in Europe. It allows ecologists to study more than 100 species of water species interacting within a natural environment. The aquarium is regularly monitored to make sure that chemicals do not exceed certain concentrations in the water, thus, keeping the fish healthy and alive (Libelium, 2015). Libelium is a leading IoT devices supplier in Europe. They have installed smart water sensors

that help measure the physical and chemical substances several times in an hour, providing a higher accuracy than the traditional daily check (Libelium, 2015). The IoT devices they installed provide real-time information about changes in the chemical properties of the water. This allowed them to monitor the status of the aquarium based on chemical parameters that they have defined. If those parameters are maintained in balanced proportions, they ensure a healthy environment for the fish living in the aquarium, which helps experts continue to protect some of the endangered sea creatures that have been kept in the aquarium.

4.1.4.2 Waste Management System at Bee'ah

In 2015, Bee'ah, the Sharjah Environmental Company has launched a new system to track and monitor waste collection vehicles across the city (Sharjah Update, 2015). The system records and communicates GPS locations of vehicles in real time, and provides them with optimized routes based on traffic conditions and bins locations. This route optimization feature saves a lot of time and fuel for the company. The system also receives weight data from built-in weigh scales in the vehicles, indicating the total weight of collected waste, hence directing the driver to the tipping location when the vehicle is full. Over time, the system can analyse waste generation trends in different areas, and hence, it can predict the volume of generated waste in different neighbourhoods at different times of the week. This feature allows the company to allocate just enough resources to perform the collection tasks. In addition, the system uses CANBUS sensors to record the driving behaviour of the driver, hence, detecting when the driver excessively accelerates or harshly breaks. This allows the management to take corrective actions against violating drivers to reduce fuel underutilization due to reckless driving, as well as to enhance the road safety (Sharjah Update, 2015).

4.1.5 Green Software Engineering Case Study

According to Penzenstadler (2015, pp. 157-186), the concept of green software engineering can be understood in two ways; either designing an optimized software code that operates with the minimum required processing power, or designing software to serve a green purpose that promotes sustainability. Sustainability is a concept that has five correlated dimensions; which are individual sustainability, social sustainability, economic sustainability, environmental sustainability, and technical sustainability (Penzenstadler, 2015, pp. 157-186). The objective of sustainability is that each of these dimensions should be able to last as long as possible to serve the other dimensions, and therefore, enhance the entire ecosystem of life on

the planet. The case study below shows an example of how software was designed to serve a sustainable purpose that tackles some of the above-mentioned dimensions.

4.1.5.1 BMW Car Sharing System

In 2012, BMW introduced a new initiative called DriveNow. It is a short-term rental service for customers who are looking for flexible locations for car pickup and drop-off (Penzenstadler, 2014, pp. 44-53). The car sharing system was developed on a web application. A user can register to the system online, and then he can do different transactions, including car reservation and billing. Of course, the web application needed to track every vehicle in terms of location and availability status, therefore, a meter and a communication transponder were installed in every car in the fleet, allowing the web application to manage all vehicles and store all usage and financial activities in a central database (Penzenstadler, 2014, pp. 44-53).

Penzenstadler (2014, pp. 44-53) has collected information about this case study through a series of interviews with the leaders of the DriveNow project. She has also conducted research about the business models of hybrid cars and the car-sharing concept. She has used the five sustainability dimensions mentioned above to measure the benefit gained from this initiative towards a more sustainable ecosystem of life. The evaluation was based on whether this system had a clear purpose to serve sustainability, and more specifically, environmental sustainability. For that evaluation to succeed, there had to be a stakeholder for environmental sustainability within that project, and fortunately, there was. The project team from BMW has declared that in addition to promoting hybrid cars, the objectives of this initiative is to promote the concept of shared-cars service rather than being owned by individuals, thus, reducing the negative impact on the environment.

4.2 Case Studies Analysis

Through the above case studies, the overall finding is that as much as the technology development is necessary and unavoidable, there is a need to take environmental conservation seriously. All the case studies above have proved the steps taken by various industries utilizing information technology to come up with ideas that help in environmental conservation. Also, in all case studies, the organizations had the objectives of reducing operational cost, as well as adding values to their financial return, to the society, or to the environment. It has been argued that technology is good for sustainability, but its outcomes are not always only positive to the

overall ecosystem of life. As a result, the technology approved by an organization should selectively be environmentally-sustainable besides meeting the demands of the customers.

On virtualization, the emphasis is on the need to adding agility in their deployments. Virtualization serves the business requirements while saving the environment. This may not seem that effective as the power consumed in running, cooling, and maintain data centres forms 86% of total power consumed by information technology (Masanet et al., 2013). Yet, the role that server virtualization plays in reducing datacentres energy consumption is massive. A single server requires a minimum amount of electric power to turn on and stay awake. Apart from that, there is the computing power which is utilized in actual processing and computations. In the Coca-Cola case study, the reason behind the high-power consumption is because they had so many servers, where each of them runs applications that require very low processing power. The result was they ended up with servers that consume much more power to stay turned on than the power they use to run the hosted applications. This concept is illustrated in Figure 6; assuming all servers are from the same model, each one of them will consume the same power to stay up. We have also generated random numbers to simulate low power consumption of single applications occupying a full server. When Cisco came in and consolidated the 80 servers all the way down to 4, they ended up having a datacentre consuming the same total power for application processing, yet, with much less power for keeping the servers up. As illustrated in Figure 7, this practice has resulted in a huge saving in electric energy, especially with the other consequent savings in cooling and space requirements.

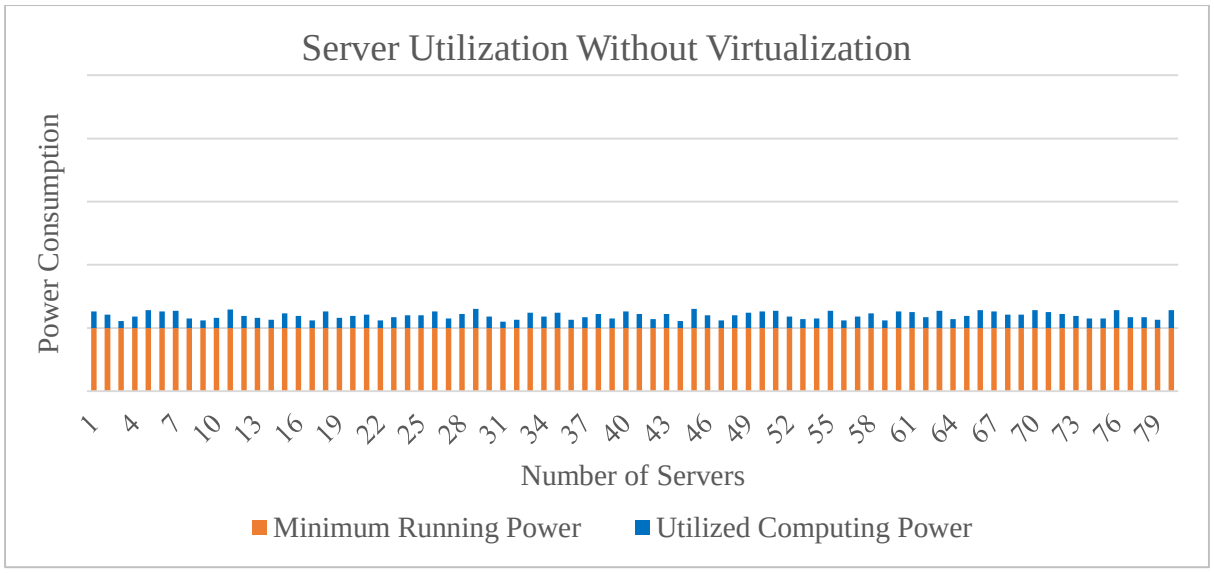

Figure 6: Example of Server Utilization Levels Without Virtualization

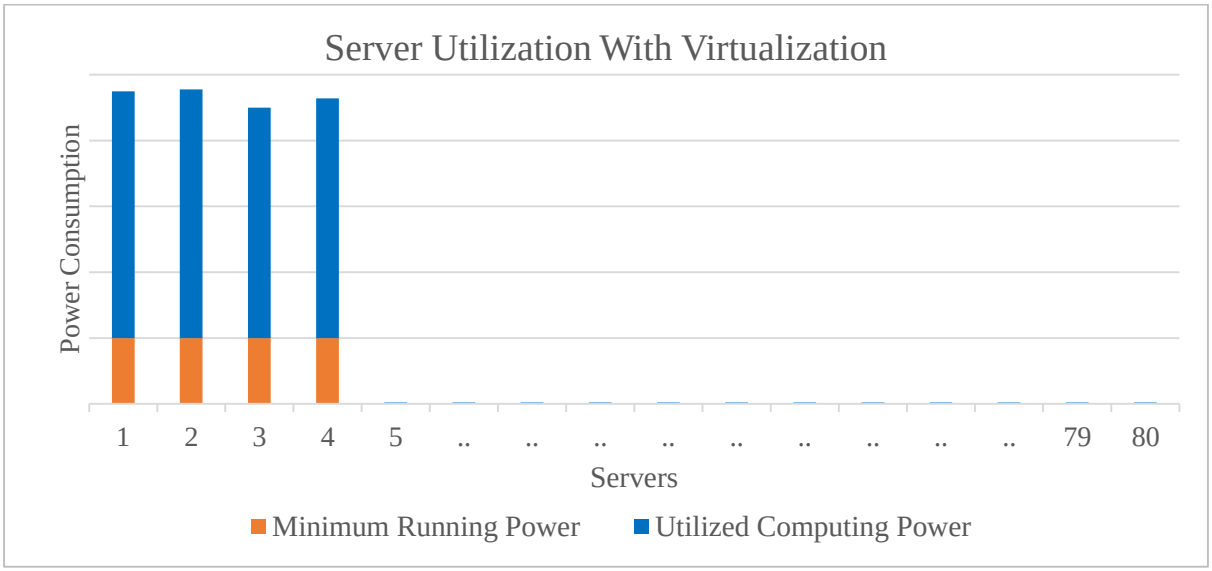

Figure 7: Example of Server Utilization Levels With Virtualization

Cloud computing is one of the efficient energy consumption technologies currently adopted by some organizations such as Google. With optimization approaches, Google data centres utilize less energy by 50% compared to typical data centres. Consequently, the technology supports the conservation of the environment through efficient use of organization resources. Google is also playing a smart strategy to increase cloud adoption, which is to spread the cloud culture among its employees and customers. With G Suite, formally called Google Apps, it has proved to reduce carbon emissions by 65% to 90% from customers who purchased this bundle moves most their corporate communication and collaboration tools to the cloud. According to the IDG survey, the substantial benefits of subscribing to a cloud service are attracting a large number of companies to consider moving to the cloud, and even look for business opportunities that can leverage cloud computing to them.

The case study where Rolls-Royse has adopted SAP shows clearly how the organization reduced paperwork significantly. That added value to the environment by reducing the demand paper production, hence saving cutting trees, power, and water consumed in the paper production process. Besides that, the main objective why Rolls-Royce adopted an ERP is to enhance their internal productivity. They were able to fulfil customer orders faster than ever, which improved their relationships with their customers (Yusuf et al., 2004, pp.251-266). That

has also given them more opportunity to expand their business to reach to new customers. Few years after the implementation was complete and stabilized, it became clear that this case represents a perfect example of how the role of information technology has grown in business to serve not only reducing cost, but also to become a profit generator (Yusuf et al., 2004, pp.251-266).

For green software engineering, the concept that Penzenstadler (2014, pp. 44-53) is trying to highlight is the possibility to integrate all dimensions of sustainability in one project. The main key to do that is to have stakeholders with sustainable organizational objectives undertaking all the dimensions. Yet, the challenge in getting those stakeholders on board is sometimes the unclear visibility of positive effects of green requirements. That is because positive and negative impacts on sustainability are classified to levels of orders, where first-order impacts are easily perceived because they show direct results, while last order impacts are harder to see since they show results only through a chain of events. According to Penzenstadler (2014, pp. 44-53), in the car-sharing system case study, the first order impact was the resources consumed to run the system itself, and that includes the processing power of the devices running the application and the servers and databases communicating with the application. This impact actually counts as a negative impact, since it is all about consumption. The second order impact was the resources on the street, and that includes the shared cars themselves along with their fuel and maintenance costs. This also counts as a negative impact. These resources consumed by the cars in the second order impact are actually the same ones that would've been consumed by other individually-owned cars that would've been used instead. Hence, that's where the third order impact starts to get clear, which is reducing the number of individually-owned cars along with the resources they consume, and this is the significant positive impact in the chain (Penzenstadler, 2014, pp. 44-53). The levels of order in this project are summarized in Figure 8 below.

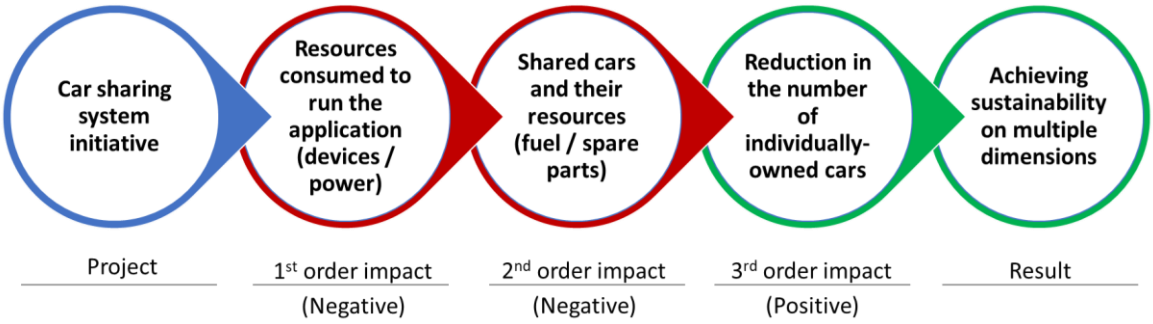

Figure 8: Summarized Impact Levels of Order in the Car Sharing Project

The same concept of impact levels of order applies to the Rolls-Royce case study mentioned above. At the early stages of the project, the management was sceptical about the value that the project is going to add to the organization. The reason is that the first order impact was that they endured a huge financial cost for purchasing over 1,000 new PCs, over 6,000 software licenses, and a whole new set of servers. The second order impact was that implementing SAP had to create two new roles at Rolls-Royce, which are MRP controllers, and Capacity owners, which had to be occupied with a large team. It was about time till the last order impact started to give results when the organization's performance started to enhance, and they were able to deliver orders on time, allowing them to seek new customer opportunities.

4.3 Conducted Interviews

Below are five semi-structured interviews that have been conducted with different professionals in different related fields. Their answers were summarized to what relates most to the research question, which gives more highlight on the problem discussed in this dissertation as well as potential solutions.

4.3.1 Interview 1: Utilizing Technology in Environmental Management

This interview was conducted with Khalid Al Huraimel, the Group CEO of Bee'ah, the Sharjah Environmental Company, UAE. He has a wide exposure to different technology projects that were implemented in different parts of the world. He also works his best to facilitate innovative technology in the organization he heads.

4.3.1.1 Question 1: Tell us about the organizational goals of Bee'ah and your role in achieving these goals.

Bee'ah was set up to tackle all the environmental challenges in the region starting with Sharjah. We look at waste management and air quality and water quality. Bee'ah is a leader now in the region. Bee'ah is successful because it is innovative in its approach by looking at latest practices and technology in the industry.

4.3.1.2 Question 2: How important is the awareness of an organization of its social responsibility towards the environment?

This is very important, for us to succeed we need to create awareness for the public. Now Bee'ah is investing a lot in the infrastructure to tackle the challenges of managing the waste and the environment. However, without the support of the residents and the public, we will always face a challenge in going forward. Bee'ah is investing a lot in awareness and education. We have various programs, including the Bee'ah School of Environment for school students. We also provide a continuous house to house awareness where our teams visit family and provide them with. So, it is extremely important to have the support of the public and engage them to achieve our goals.

It also involves engaging the employees. We utilize technology, internal mobile apps, and social media to keep then updated and engage them in our environmental activities and programs. Even at the workplace, we use technology to empower communication and collaboration to save time and paperwork.

4.3.1.3 Question 3: What are the most common practices that organizations are adopting to play a role in this social responsibility?

First, you have to have the basics in place, for example, the ERP, so the business can function properly. With Bee'ah, we have SAP, which we are still implementing it and enhancing it phase by phase. There are other technologies in the actual business stream. For example, when it comes to our waste collection business, which is one of our core businesses, we have the fleet management software which enables us to track vehicles and optimize routes. That's crucial for many reasons. First, our more is more efficient, second, we save fuel and power, which leads to reducing the carbon footprint. Also, we are introducing a new set of fleet which runs on gas, electricity, or solar power. The direction of the management now is to have a clean fleet, especially we have a huge one (1000 vehicles), so we need to reduce carbon

footprint while cleaning the city. So, we will utilize technology to reduce the number of kilometres we drive, reduce fuel, be more efficient.

On the other hand, after waste is collected, we need to segregate is and process it to recover the waste. We have invested a lot in one of the largest waste recovery plants in the middle east. Currently, it is a mechanical and manual process to segregate waste. Part of it is staff who work on a conveyor in a segregation room to manually pick the waste that was mechanically missed. Now, we are introducing robots that use AI, and they have 95% accuracy in segregating waste. So now the process is more automated, faster, and it can work 24 hours a day, and that makes Bee'ah the first to introduce this technology globally.

4.3.1.4 Question 4: Can these practices be cost-effective? And what is the environmental value gained from these practices compared to their financial costs?

A lot of these will be cost-effective in the long term. For example, the new robots technology in the MRF (Material Recovery Facility) will have a high capital expenditure cost, yet, in the long run, we will be able to recover that cost. The same thing with the Fleet Management software, which we have put a big investment in the tools and the software and the tracking devices and all the technology, but in the long run it will save a lot of fuel and spare parts. In addition, that will, of course, have a value added to save the environment, which is at the end our main organizational goal. Even in investing in ERP solutions, where the staff get more productive and efficient instead of relying on manual work and waste time and other resources.

4.3.1.5 Question 5: Recommendations to other organizations who would like to adopt technology to help the environment.

For companies to survive and prosper today, they need to use technology and be innovative. The world is changing, and it is going towards more cyber environments like e-commerce. Organizations need to continue to adapt to this and adopt technologies. There are always new technologies that improve the environment and help save it, by providing cleaner air and cleaner water and clean streets. This is a very fast moving and growing industry, and it needs a lot of attention and investment to catch up.

4.3.2 Interview 2: Virtualization & Cloud Computing

The interview was conducted with Badr Hubais, Head of ICT, Bee'ah, the Sharjah Environment Company, United Arab Emirates. Based on Badr's work, his experience was

highly related to server virtualization and cloud services, and thus, the interview was focused on Server Virtualization and Cloud Computing as an example of green IT practices.

4.3.2.1 Question 1: Tell us about your role at Bee'ah and how do you contribute to achieving its organizational goals.

I'm the Head of ICT, the senior IT executive in the company. My role is to enable and support the business cause of the company, which provides sustainable solutions in environmental and resource management. He assists in improving efficiency and leveraging technology to push these environmental goals further.

4.3.2.2 Question 2: How do IT professionals in UAE perceive the significance of virtualization as a green technology?

The way they see virtualization is more towards adding agility in their deployments. They view virtualization as a lean way to serve the business requirements with a tangible effect on saving the environment by replacing paperwork with electronic processes. However, what they might not perceive completely is the high-power consumption of data centres to run virtual services. For example, when vendors do their sizing, they don't always take virtualization into consideration. They would propose hardware requirements based on distinct systems which decrease utilization in virtualization and increases power consumption.

4.3.2.3 Question 3: Is Virtualization considered a green technology? From which perspective does it harm the environment and from which perspective does it contribute in saving it?

Virtualization on its own if not utilized properly does not provide high gains on reducing the negative impact on the environment. The idea behind virtualization is to operate your virtual machines with the minimum required resources to the point that you should be able to pool your physical resources and power down the resources that are not used at the time. Thus, failing to do that will result in greater harm to the environment by running idle infrastructure consuming lots of power.

4.3.2.4 Question 4: How can the organizational culture play a role in utilizing technology effectively and environment-friendly?

In terms of technology, the organization should provide proper awareness and training for users to understand the applications cost-wise and environment-wise. For example, if a company adopts virtualization, the business owner might think that resources are taken away

from his ecosystem, and therefore he might object to retain these resources in case he needs it. However, the business owner needs to understand how this technology doesn't reduce his requirements, but it reduces only the minimum limit of his requirement, and it, in fact, gives him a higher maximum limit of requirements especially when using dynamic resource allocation.

4.3.2.5 Question 5: How can the optimizing practices of utilizing data centres change the negative impact on the environment?

This happens through more efficient utilizing of resources based on the business demand for resources. In addition, sourcing energy from renewable sources plays a significant role in contributing to lower the negative impact on the environment.

4.3.2.6 Question 6: How do the technical skills of IT professionals play a role in reducing the negative impact on the environment.

This happens when they do better work in capacity planning and demand management, leading to higher optimization of resources, and reducing the power requirements of data centres.

4.3.3 Interview 3: Business Process Automation

The interview was conducted with Amin Al Zarouni, Director of Public Sector, SAP, Dubai, United Arab Emirates. Amin has a long experience in assisting organizations adopting ERP solutions, which is an example of a business process automation practice. Hence, the interview focused on business process automation as a green IT practice.

4.3.3.1 Question 1: Tell us about your role at SAP and how do you contribute to achieving its organizational goals.

His role is about managing business development opportunities the government sector in the UAE. He works on enabling and driving the sales process in SAP by finding and creating opportunities for government organizations in the market to assist analyzing their processes and help them adopt advanced technology solutions.

4.3.3.2 Question 2: Tell us about SAP's initiatives in running environmental-friendly projects to its customers.

Part of SAP strategy is to empower cloud computing technology. It builds more services on the cloud every day, which is more environment-friendly than individual organization server premises, as it eliminates the need for customers to build its own IT infrastructure. Also, SAP

drives a trend with its customers called “Digital Transformation”, which encourages them to move their processes to the cloud. One of the practices is providing ERP solutions to the customer, which enhances the efficiency of their business and enable them to eliminate the manual paperwork.

4.3.3.3 Question 3: Does business process automation strategies help in reducing the negative impact on the environment despite its high requirements for IT infrastructure?

In addition to helping customers minimize the manual paperwork, our cloud infrastructure would reduce the need for each company to build its own infrastructure. Rather, SAP pools its infrastructure to be shared among its customers. That would distribute the infrastructure capacity among the customer ensuring a high optimization utilizing servers.

4.3.3.4 Question 4: How can the organizational culture play a role in utilizing technology effectively and environment-friendly?

There is a direct relation between the level of innovation of a community and its level of adoption to trending technology. Innovation is also related to the awareness of the environmental cause and other trends related to the well-being of humanity. The more innovative the culture is, the more it will drive the organization to adopt cloud solutions and digital services, hence positively affect the environment. This culture depends on age. The new generations that are entering the business today are more willing to adapt to new technologies, including business automation technologies.

4.3.3.5 Question 5: What is the emphasis of the IT professionals on affecting this culture positively?

The business has different stakeholders. Each one of them has a role in the positive change, and IT professionals have a big responsibility of driving the digital agenda. For example, Dubai’s Smart City agenda is currently being led by highly professional IT leaders who are successfully making positive emphasis on the culture of utilizing technology, and hence, contributing to reducing the negative impact on the environment.

4.3.4 Interview 4: Internet of Things

This interview was conducted with Dr. Imran Zualkernan, a computer engineering professor at the American University of Sharjah. He has a long experience in teaching courses tackling the latest technologies, including Software Design, and Internet of Things.

4.3.4.1 Question 1: Tell us about your role at AUS and how do you contribute to achieving its organizational goals

I'm a faculty member. Therefore, teaching is our primary goal in the university. Also, we engage in administrative work including curriculum design and governance. Lastly, we do a lot of research, which is contributing in producing new knowledge, which is an important goal for the university.

4.3.4.2 Question 2: What is IoT, what are the common drives to use it in everyday life, and what are the fields in which it is being used?

IoT came out because of three main reasons; first, the wireless networks have become pervasive, cheap, and reliable. Second, the small microcontrollers and sensors have become wireless-enabled and very cheap. Third, storage has become very cheap as well, and we can now store a lot of data. So, because of the low cost, we can now use IoT on many fields, and we can now instrument everything around us, from your coffee pot to your car do your garden, and you can collect data on a continuous basis.

The technology that allows us to process this data is called "Big Data", which is also coming in handy at low costs. Thus, we can analyse big data now, which allows us to do meaningful analysis with the data we are collecting. In terms of applications, IoT has been applied almost everywhere, with more in some areas than the others. People claim that there is a lot of applications in the industry, including Industry 4.0. There are also big applications in Smart Cities, transportation, and agriculture. Energy is a field tackled in smart cities, where the concern is to optimize energy consumption, water consumption, flow of traffic, and sewage. The general term for this is called "distributive networks" within the city or the country where utilities are distributed.

4.3.4.3 Question 3: From which perspective does IoT harm the environment and from which perspective does it contribute in saving it?

The problem with IoT is if it takes off, which will most probably do because it makes a lot of economic sense, a lot of hardware will become obsolete very quickly which creates a lot of waste. That will create a problem where people need to be aware how dispatch batteries, mobile phones, computers, and other edge node devices correctly after they die.

There is very large number of sensors which are consuming energy. Although that might seem to be a problem, most of these sensors operate on very low power, which doesn't

add up much compared to old conventional devices. Also, IoT devices are powered by either solar power or batteries which can last for an average of 10 years, which indicates how IoT devices consume minimum power. Yet, the power consumption will be more of a problem at the backend. When you start processing that date, the data centres will consume very large amounts of power. On the other hand, It can be used in many fields including agriculture, and to save water, electricity, optimize traffic flow for saving energy. It can also make the industry very efficient. So, the positive impact is obviously a lot more than the negative.

4.3.4.4 Question 4: How can IoT be utilized in optimizing power consumption of other electronic devices themselves and the way these devices operate?

At the lowest level, an individual device is already programmed with a power management system to take care of optimizing power consumption. So that's not really the job of IoT. What IoT does here is more related to the consumer space, including smart homes for example. So, if a consumer has multiple devices at home, IoT will optimize how a smart home can level the load in the households, so different devices don't work at the same time in order to cause fewer spikes.

4.3.4.5 Question 5: How can IoT be used to monitor environmental phenomena's?

It can be used to monitor various aspects of the environment including water levels, air quality, moisture content in the soil and so many other things. Although these applications have been there in the technology fields long ago, IoT can do this on a larger scale where you can install a very large number of sensors in a particular domain and get these sensors connected in real time. So, the advantage or IoT here is adding a more dynamic communication attribute to the sensors being used. In addition, edge devices are now important to consider utilizing IoT. For instance, you can today utilize microcontrollers, mobile phones, and even drones to monitor your environmental domain within different scenarios.

4.3.4.6 Question 6: How can the culture of end users play a role in utilizing technology effectively and environment-friendly?

Unfortunately, there is only a small population of people who would consciously look for things to save the environment. In the end, most users might not care much about the environment, but they would rather focus on their cost and convenience. For example, they will use electric cars only if they are more comfortable to drive, if they eliminate cost on gas, or if they reduce the maintenance hassle of conventional cars. Similarly, on a farm, people might

not use sensors monitoring their water consumption because they necessarily care about the environment, but rather because it reduces the water bill. As most people look for adding value their own lives and businesses, IoT applications that save the environment need to have a significant value added to the consumer as well.

The good news is, in most cases, IoT devices actually do add value to the consumer. Going back to the same example of agriculture and water monitoring, and the example of load levelling in smart homes, these are applications not only help save the environment, but also add a significant functional and cost-saving value to the end user. It is hard to think of an example where IoT is good only for the environment. In most cases, IoT devices work on optimizing resources, and because it is optimizing resources, it is economically feasible.

4.3.5 Interview 5: Value Engineering

This interview was conducted with Dr. Alaa Ashmawy, the Dean of Engineering at the American University in Dubai. He has a civil engineering background and worked on a lot of research where he tries always to involve value engineering concepts in his evaluations.

4.3.5.1 Question 1: Tell us about your role at AUD and how do you contribute to achieving its organizational goals

My position is the dean of the school of Engineering. The School of Engineering is 1/5th of the university. So, I contribute from the academic success of the university by supporting the students and supporting the academic mission of the university.

4.3.5.2 Question 2: Tell us about your research in regard to Value Engineering and Value Management.

My original area of research is in geotechnical engineering. Value Engineering is a topic that is pervasive throughout different disciplines. Thus, rather than implementing a research on value engineering, researchers are researching how to implement the concepts of value engineering on different disciplines. Value Engineering is an agile concept, and it is an integral part of many aspects. For instance, I was able to teach its concepts Geotechnical Engineering, Construction Management, Managing Mega Projects, and Construction Productivity.

4.3.5.3 Question 3: What is Value Engineering, what are the common drives to use it in corporations, and what are the fields in which it is used?

Value Engineering is a systematic process by which you improve the value of a product, a system, or a service, and while you improve the value, you also reduce cost. This concept is driven by the need for achieving certain goals in certain products while reducing the costs.

The common drive varies depending on the objectives of different corporations. For example, in service-providing firms, the main drive is to improve staff productivity and to reduce cost in terms of wasted time. In goods production organizations, the drive is to increase the value of the product to the customer and at the same time reduce cost by optimizing resources.

Value Engineering is a concept that can be used in any field even outside Engineering. Nowadays, it is used to reduce costs in products, processes, and even managing projects. This is due to the agility and integrability of its principles.

4.3.5.4 Question 4: What are the principles and basics of value engineering?

The basics are that you have to go a systematic process to define a value, assign a cost to the product or service. This systematic process is a six-phases workshop, which are data collection, function identification, data analysis, the creativity phase, looking at alternatives, and approvals. It mainly relies on analysing the function, which is identifying the value and assigning the cost, and then mainly looking for alternatives through creativity means.

4.3.5.5 Question 5: How can Value Engineering principles be applied to technology projects? and how is value identified when adopting technology?

It is straightforward. We see Value Engineering in technology projects all the time. From a product perspective, we could say that adding a camera or a fingerprint reader to a mobile phone adds value to the user. Also, these concepts can be applied if you use technology as a tool or as a service to the customer, like e-commerce for example, which saves the customer's time and driving effort.

4.3.5.6 Question 6: Which one usually takes more considerations in making project decisions, value added to the corporation, or value added to the environment? Do these two values necessarily conflict?

They don't necessarily conflict. In most cases, companies provide a service or a product that add a profit, which is a value defined by the company, aligning with another value defined

by the community. This happens especially if the company has a Corporate Social Responsibility (CSR) value assigned to their objectives. Usually, these programs originally have long-term financial agendas, and they use them as marketing techniques to show that they care about the society and the environment, attracting larger segments of customers. Yet, that would be of no harm if the outcomes of these programs add a real benefit to the community and the environment.

It could be conflicting in rare cases if corporations are looking for a financial value, especially if that contradicts with other values defined by the society or the environment. If that happens, unfortunately, the community and the environment will be less considered, and the corporate objectives will override.

4.3.5.7 Question7: Are there techniques that enable Value Engineering to reconcile between both priorities (corporate financial value and environmental value)?

First, organizations need to recognize the importance considering the community and the environment, and thus, should assign a value to them. Second, governments should interfere and stipulate some requirements for the companies to abide by, and they should enforce companies to assign a value to the environment within their objectives.

4.3.5.8 Question 8: How can the organizational culture play a role in considering social responsibility towards the community and the environment?

That varies from company to another. In some organizations, you can sense the awareness and the environmental responsibility within the internal culture, and in other organizations, you don't. That culture can have a long-term stake in the community, and hence a better effect to the community.

4.3.5.9 Recommendations from the professor.

The concept of value engineering can be widely applied in different disciplines. Organizations need to work on improving the quality of life of people by assigning a value to the environment and to different aspects of social development.

4.4 Interviews Analysis

All interviewees have agreed that green technology approaches have a bright adoption future. They believe that the mentioned approaches can have a great value added to the environment as well as to the economy, the businesses, and the society. The key argument for

all of them is to minimize waste of resources in any business practice, increasing the margin between costs and gains. It is important to them that the organizational culture also plays a noteworthy role in influencing and utilizing the technology through creating awareness to their employees. Innovative organization cultures will drive the organizations to promote the suggested technologies, thus increasing the positive impact on the environment. IT specialists have a significant role in influencing positive organizational culture.

Khalid Al Huraimel is the Group CEO of Bee'ah, the Sharjah Environmental Company in the UAE. According to him, Bee'ah has the responsibility of handling all environmental challenges in the area. The organization believes that creation of awareness among its critical stakeholders is essential in establishing sustainable technology. The organization has adopted some relevant practices such as ERPs, fleet tracking system, and automotive industrial robots that add environmental value in addition to the business value. Accordingly, it promotes a positive impact on the organization social responsibility, business functionality, and friendly technology. The officer recommends other organization to adopt new and advanced technology aimed at preserving the environment.

Badr is the Head of ICT at Bee'ah, the Sharjah Environment Company in the United Arab Emirates. According to Badr, IT plays a significant part in creating a sustainable atmosphere in environmental and resource management. Moreover, the professionals in IT field perceive the importance of server virtualization as a means of improving their organization's agility. The technology allows service providers to achieve their maximum infrastructure utilization with a more diverse base of customers around the world. This idea can be illustrated by comparing Figure 9. with Figure 10 below. Figure 9. displays how a company-owned data centre in an organization is approximately utilized during a working day. It is noticed that most employees log in to their computers and start using their business applications in the morning, which results in high traffic within a short period of time. Later after mid-day, traffic starts reducing slowly till the day finishes. The problem with this is that servers work at their maximum capacity only during the peak hour, and they are underutilized otherwise, especially outside of working hours.

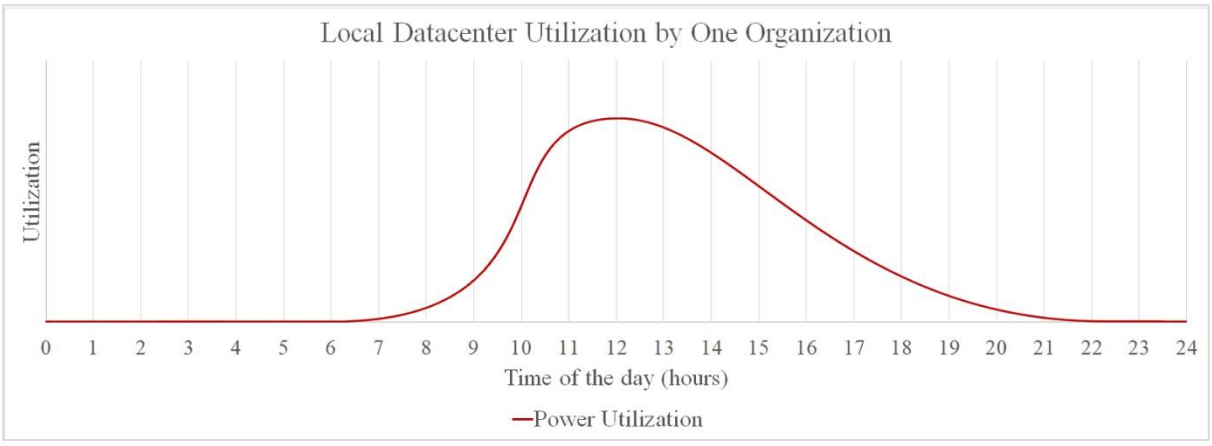

Figure 9: Suggested Local Datacentre Utilization by One Organization

In comparison, Figure 10 displays an ideal scenario where a cloud service provider has a worldwide base of customers. Since those customers reside in different time zones, they will obviously start working at different times. Hence, server traffic will be distributed along the day, allowing to achieve a maximum data centre utilization.

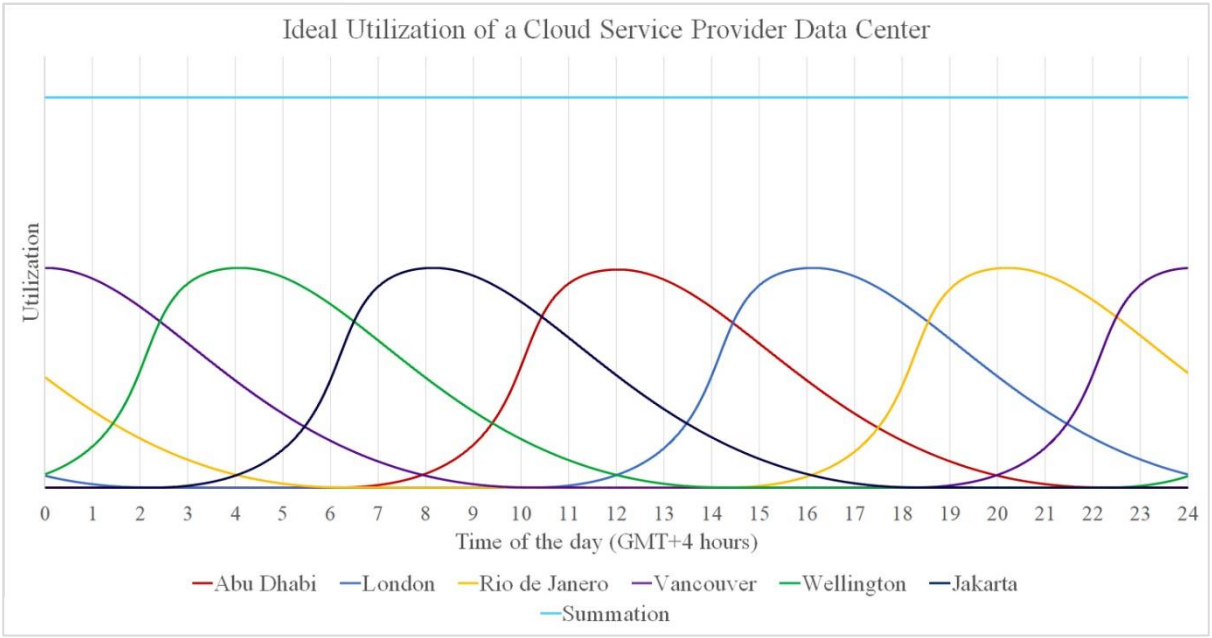

Figure 10: Suggested Ideal Cloud Utilization for Multiple Customers in Different Time Zones

Amin Al Zarouni is Director of Public Sector at SAP in Dubai. According to Amin, SAP has a strategy which supports and empowers the technology of ERPs. Additionally, SAP approves a "Digital Transformation" forum that has been influencing their drive to embrace cloud services. The organization has sophisticated infrastructure shared by each company,

hence reducing the need to create their own infrastructure. Additionally, SAP pulls its available resources for sharing with their clients in the market, which ensures resources optimization.

Dr. Imran Zualkernan is a computer engineering professor at the American University of Sharjah. According to the professor, the primary drivers influencing IoT is reliability, sensors low cost, and pervasiveness of wireless networks and microcontrollers. IoT allows the organization to process "Big Data" with minimum resources. One of the primary concerns about IoT is that when most of the devices become obsolete, disposing them will be a major problem. However, IoT technology has more positive effect on the environment than negative. For instance, the devices have low power and energy consumption, hence making them more environmentally friendly. The technology can be applied in large-scale monitoring water levels, moisture content, as well as air quality by using various sensors installed within the system.

Dr. Alaa Ashmawy is the Dean of Engineering at America University in Dubai. The Dean asserts that value engineering is an agile concept and has become a vital part of various aspects of the society. The idea of value engineering has driven the desire to accomplish goals in particular products in the process reducing costs. The principles and the basics of value engineering are data collection and analysis, function identification, creativity phase as well as seeking for alternatives, and approvals. The concept can be employed in adding more features in smart devices to make them smarter and valuable to the end-users. Value added to the environment plays an important part in making decisions regarding projects. Organizational culture has a significant role to play in considering social responsibility to the community besides being environmentally responsible. The Dean recommends that organizations should focus efforts on adding quality to life through assigning a value to the environment.

4.5 Strengths of the used research methodology

This research has been conducted by many experienced researchers beforehand. Therefore, it gives us a base upon which we can analyse previous work properly. The conducted research work is very deep and well referenced, hence can be considered reliable.

Different research work from different researchers and interviewed experts have been used, hence the necessary information required to make the necessary evaluations are available for drawing accurate conclusions. The researchers worked at various times using different respondent samples hence have based their findings on their independent studies. In addition,

the different research work has been conducted by researchers who had all the necessary tools, equipment, and expertise that was required to conduct an objective study and draw realistic conclusions. The various researchers based their results on real-time facts. These results have been well documented and illustrated in their reports and thus are very reliable.

The interviewed experts have worked in their corresponding fields for long enough to build their hands-on experience about the best practices in utilizing information technology. They have also worked in different environments and experienced different cultures. Comparing their results will give us a more accurate perspective on which we can base our conclusions.

4.6 Weaknesses of the used research methodology

The weakness of this research method is that it is prone to other researcher's inaccuracies. This means that in case they made errors, we are in no advantage to verify. This may deem this research inaccurate to a certain extent. There is also a probability that the researchers may also have been biased in their conclusions. This means that if we take everything they say at face value, then there is a chance that we might be misled to an extent.

In order to minimize this vulnerability, references were chosen very selectively. Credible and most recent books and online reports and case studies have been referred to. Selected journals have at least a 1.0 impact factor and at least 15 previous citations. In addition, the interviewees were nominated to be people who have enough experience in working directly in the field of information technology or environmental management or both, which gives the research more realistic, on-field, and reliable results.

5 Research Findings

The research hypothesis that we are testing is that green information technology is viable financially and that it can result in a substantial decrease in environmental pollution. To adequately test this, theoretical evaluation will be one of the three the main research method used. This will involve evaluating and analysing the work of researchers who have previously conducted similar research. We will rely on the extensive studies that these researchers have undertaken. Then, results from the theoretical evaluation will be compared with results from the other two methods, which are analysing case studies and conducting semi-structured interviews.

Much research has been conducted by many researchers with the aim of evaluating how these projects influence the rate of pollution in given companies and the world at large. Certain projects have been undertaken by companies in a bid to try to reduce environmental pollution. This includes server virtualization, cloud computing, process automating software, green software engineering, and value engineering. These methods have been embraced by many companies, and success stories were told. All these successes have been analysed by various researchers and documented in books, journals, and other online sources. In addition, case studies were published to elaborate on how and why these approaches were undertaken, and what the results were after adopting them. Examining this well-documented work will give us the base through which we can analyse our project and make a definitive judgment.

The final research methodology is conducting semi-structured interviews with experts and professionals in the fields of information technology, Environmental Management, or both. A total of five interviews have been conducted with five different experts, and their feedback has been received on different questions that vary based on their experience in the field and type of business they work in. This has helped us gain deep insight about how green information technology has changed the entire business perception and ways through which it has helped reduce pollution.

5.1 Proposed Solution

In all cases, the idea of any environmental technology approach is managing and saving resources. Thus, we will discuss techniques that help save resources, and hence, save power and heat dissipation, as well as monitoring natural resources to protect them from being wasted or destroyed. Using research and the mentioned methodologies, it has been verified that server

virtualization, cloud computing, software process automation, green software engineering, and value engineering are effective techniques to improve efficiencies, reduce heat dissipation, save resources, and monitor environmental resources. Hence, those techniques are effective in reducing the environmental degradation caused by technology and the IT sector. Adopting Green IT projects is undoubtedly an answer to information technology-based environmental pollution. There are many approaches which have been identified that can go a long way in helping achieve environmental sustainability. It is widely known that hardware assets are among the most expensive components in any institution. Underutilizing these elements thereby results in costs that would have easily been avoided. Energy conservation not only reduces pollution but it also causes a significant reduction in operational costs which is the major goal of any business.

Server virtualization and consolidation aim at reducing the number of physical servers in an organization. For example, if an accounting application is connected to a server dedicated for accounting purposes only, and other servers are dedicated for different purposes, the overall effect is that there will be a high number of underutilized servers. That leads to a lot of unnecessary energy emissions which translates to environmental pollution. Server visualization aims at reducing this problem through special configurations that convert one physical server into multiple virtual servers. Each virtual server behaves as a separate server thus separate tasks are isolated. Many applications can, therefore, run using the same server independently, consuming only the power needed to run one physical server. Fan et al. (2007) found that peak load of an application is much higher than the average load of the same application on the server. If the data centre is fully integrated, the ratio of peak to average reduces considerably resulting in less number of servers. This ensures that the servers are utilized to the maximum (Jenkin et al., 2011, pp.17-40). The bigger real implication is that there is less energy emitted, and the costs of housing and operating the many servers as well as maintaining them decrease substantially. This, therefore, means that not only this method is financially viable, but it also helps protect the environment to the maximum possible (Jenkin et al., 2011, pp.17-40).

Cloud computing is also another method that should continually be embraced by institutions and individuals everywhere. It facilitates storing documents and hosting applications on the internet. This helps in saving a lot of companies' on-premise server space. Cloud service providers use large-scale virtualization techniques so their hardware can be shared between multiple organizations. Cloud computing enables employees to access their

work applications and services online, which will only require them to login into their online portals to carry out their operations. Cloud computing simplifies user PCs to only perform communication, transfer data, and access online applications. Once the major processing runs on the cloud, substantial power savings could be possible at the client (user) device, and purchasing lower-end client devices would make more sense to the organization. Cloud technologies are under development and are growing fast. Cloud computing also helps in the data recovery process in case of server failure or data corruption. This is because cloud computing vendors use advanced load balancing, redundancy, and disaster recovery techniques which guarantees the high-availability of data on the cloud. Although security is a concern for cloud users, most cloud vendors provide advanced security protection to the hosted data, and hence, data can hardly be stolen or tampered.

As 86% of the power utilized by the information technology sector is consumed only in data centres (Masanet et al., 2013), practices that save power in data centres will have a significant impact in reducing the overall power consumed by the information technology sector. Adopting cloud computing can play a substantial role in achieving that saving. Table 4 below shows a breakdown of energy use and CO_2 emissions in the United States in 2013 caused by hosting business applications on local datacentres compared to cloud data centres. It is displayed that the total consumption of primary energy in the U.S. was 372,970 TeraJoules in 2013. This consumed power can go all the way down to 47,240 TeraJoules, which is around 87% of saving, by hosting the corporate applications on the cloud rather than owning datacentres. The same argument goes for CO2 emissions, which can also be reduced by 87% by moving business applications to the cloud.

Figure 11 illustrates the same date in Table 4 in a graphical format. The size of the bubbles indicates how much Peta Jouls of footprint energy is dissipated due to servers running in data centres. The red bubbles represent the energy dissipated in 2013 from privately-owned datacentres, and the green bubbles represent how much energy will be dissipated if those privately-owned datacentres are replaced by large cloud computing data centres. The first bubbles at the top are cut in half because they are the table header, and that doesn't represent reducing the footprint by half. In fact, the header bubbles represent the total footprint energy emitted, and they are the summation of the remaining bubbles underneath.

Table 4: Energy Use and CO2 Emissions in the U.S. Caused by Hosting Business Applications on company-owned Datacentres vs Cloud Datacentres (Masanet et al., 2013)

	Primary energy (TJ/yr)			CO_2 emissions (kt CO_2e/yr)		
Email	Present day	Maximum cloud adoption	% change	Present day	Maximum cloud adoption	% change
Client IT device operation	16,060	16,060	0%	790	790	0%
Client IT devices (embodied)	6,450	6,450	0%	400	400	0%
Data transmission system operation	1,520	1,600	5%	75	80	5%
Data transmission system devices (embodied)	280	300	5%	25	30	5%
Data center operation	235,200	3,900	-98%	11,540	190	-98%
Data center IT devices (embodied)	8,150	420	-95%	500	30	-95%
Data center building materials (embodied)	5	1<	-94%	1<	1<	-94%
Subtotal	267,670	28,770	-89%	13,320	1,500	-89%
Productivity software						
Client IT device operation	8,560	8,560	0%	420	420	0%
Client IT devices (embodied)	3,370	3,379	0%	200	200	0%
Data transmission system operation	750	790	5%	40	40	5%
Data transmission system devices (embodied)	140	150	5%	10	10	5%
Data center operation	82,300	2,680	-97%	4,050	130	-97%
Data center IT devices (embodied)	2,860	290	-90%	170	20	-90%
Data center building materials (embodied)	2	1<	-88%	1<	1<	-88%
Subtotal	98,000	15,820	-84%	4,900	830	-84%
CRM software						
Client IT device operation	930	930	0%	50	50	0%
Client IT devices (embodied)	1,130	1,130	0%	90	90	0%
Data transmission system operation	150	160	5%	7	8	5%
Data transmission system devices (embodied)	30	30	5%	2	3	5%
Data center operation	4,890	360	-93%	240	20	-93%
Data center IT devices (embodied)	170	40	-78%	10	2	-78%
Data center building materials (embodied)	1<	1<	-73%	1<	1<	-73%
Subtotal	7,300	2,650	-64%	390	160	-64%
Total	372,970	47,240	-87%	18,610	2,490	-87%

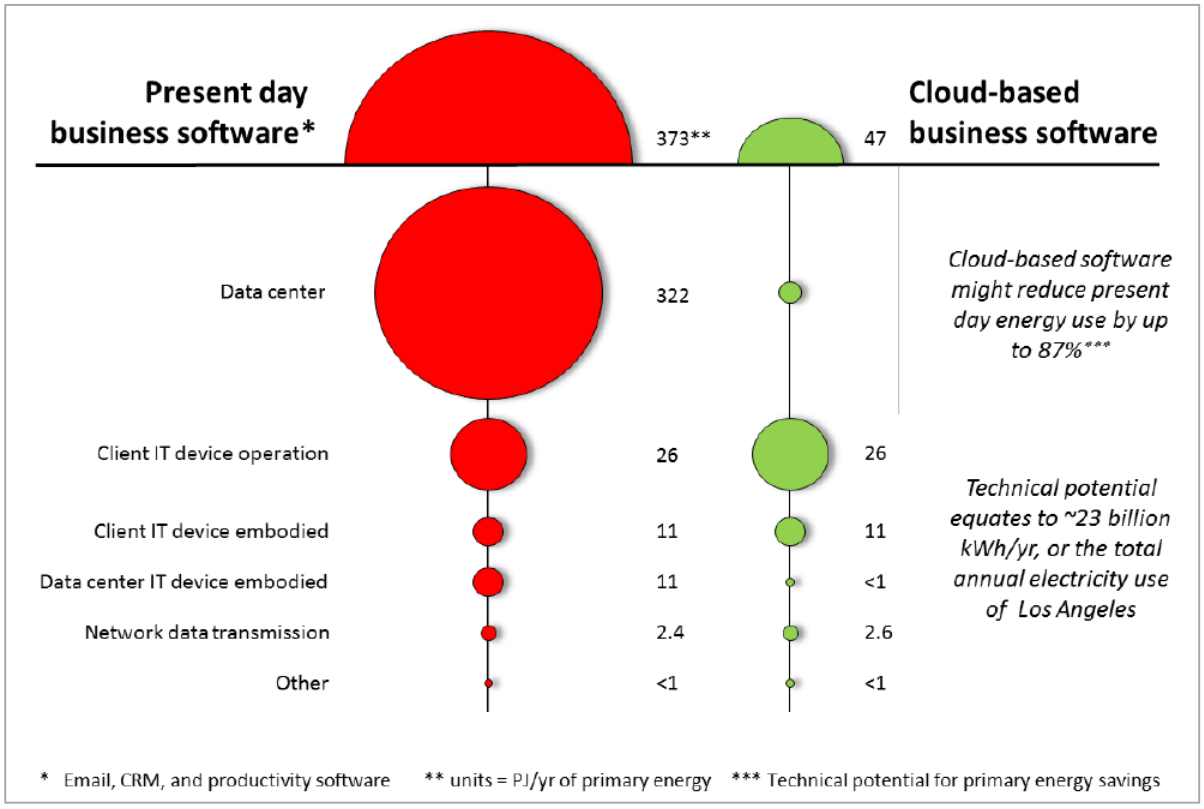

Figure 11: Estimated footprint in PetaJouls (10^{15}Joules) per year by primary energy in 2013, and cloud-based business software in the U.S. (Masanet et al., 2013)

Adopting a business process automated system in replacement for paperwork is also a very viable option for the continued operation of business (Torrecilla-Salinas et al., 2015, pp.124-144). Automated software systems are designed to work automatically with minimal human input, assuring faster communication and higher accuracy in data storage. Automated systems not only save on employment costs but they also ensure that the work generated is accelerated, recorded, and even trackable, hence, increasing the quality of produced work. Paperwork no doubt has a negative effect on the environment. Cutting trees to produce papers causes environmental degradation by decreasing the rate of generating Oxygen into the air in exchange with Carbon Dioxide. It also requires extra equipment in offices such as photocopiers and large printers, which lead to the further emission of energy during their functions. Employing personnel to operate this machinery is also a prerequisite. Elimination of such machines, papers, and the human resource required to operate the machinery results to an ultimate reduction of operational costs.

Internet of Things is another approach that can be used to make technology better able to respond to cases of unsustainability and environmental degradation. It has been used to positively influence the environment. For example, it can be used to monitor and enhance agriculture, reduce carbon emissions from exhausts, manage waste collection operations, and in fire detection systems, and in smart meters to monitor power and water consumption in households in real-time. Through the implementation of IoT in various fields, it will be easier to monitor and control power consumption of various devices. It will also enable detecting any signs of environmental pollution or degradation, allowing authorities to take quick and accurate decisions. Additionally, the initial production of commodities and machines will be based on making sure that once they are in use, their power consumption is controlled hence their negative effect on the environment reduces.

It is important for the management in an organization to monitor their performance and productivity, especially when needing to meet deadlines. However, doubling efforts and deploying more equipment to accelerate the productivity could increase resources underutilization. Thus, it is crucial to use Green Software Engineering techniques to ensure a smooth progress of projects with a maximum optimization of resources. The principles of green software engineering rely on managing projects so that they produce the highest outcome with the lowest waste of resources. This concept applies to different aspects of software project management, including hardware utilization, human capital, and even project lifecycle

methodologies. Green software engineering can be involved in various sectors of production and consumption across the globe. If sustainability is considered in green software engineering, corrective actions can be taken during the first stages of software projects, which substantially reduces cost on both the organization and the environment.

The viability of the project must be determined beforehand so that a definitive decision can be made. Value Engineering aims at reducing costs while maintaining quality thus making the project as financially viable as possible. Environmental awareness needs to be spread among individuals and organizations. In order to contribute to reducing environmental degradation, both organizations and governments need to assign a value to the environment as part of their agendas. CSR programs are a perfect example of that practice, where organizations declare their interest in helping the environment, and therefore, enhance the future health and quality of life of the society.

5.2 Conceptual Model for the Proposed Solution

This research has formed a solid understanding on how information technology can harm the environment. Thus, it was possible to develop approaches to eliminate that negative effect, and alternatively, turn it into a positive effect. Based on the proposed solution above, a conceptual model has been formed to summarize how these proposed approaches can lead to the same key technique, which is to optimize resource utilization, hence, leading to reduce environmental degradation and save financial cost. The conceptual model is displayed in Figure 12 below.

Three out of the six techniques in the proposed solution can have a direct effect on optimizing resources. Those three techniques are server virtualization, cloud computing, and business process automation. Server virtualization helps save resources by running multiple virtual machines on one physical hardware, cloud computing provides a pool of hardware resource to multiple customers over the internet, and business process automation saves paperwork and enhances productivity by reducing time. Thus, all these three can help directly in optimizing resources.

The other three techniques are used to monitor resources consumption as well as natural phenomena. Internet of things can monitor environmental behaviour and provide real-time readings of environmental activities. Thus, decisions can be take quickly. Also, value engineering and green software engineering are management approaches that monitor and

resources consumption in initiated and running projects. Therefore, reports can be provided to the project stakeholders and better resource-management decisions can be made in order to reduce cost and enhance the overall value of the project outcome.

Through optimizing resource utilization, the organization can eliminate the need of purchasing unnecessary hardware and equipment, and that will reduce the extra overhead costs in projects; thus, leading an increased financial profit for the corporation, which also reflects to increased value to individuals and consumer by getting lower-cost products and services. On the other hand, optimizing resource utilization can also lead to less power consumption in data centres. That leads to dissipating less overall heat from these data centres, implying less greenhouse effect, and finally leads to reducing the environmental degradation.

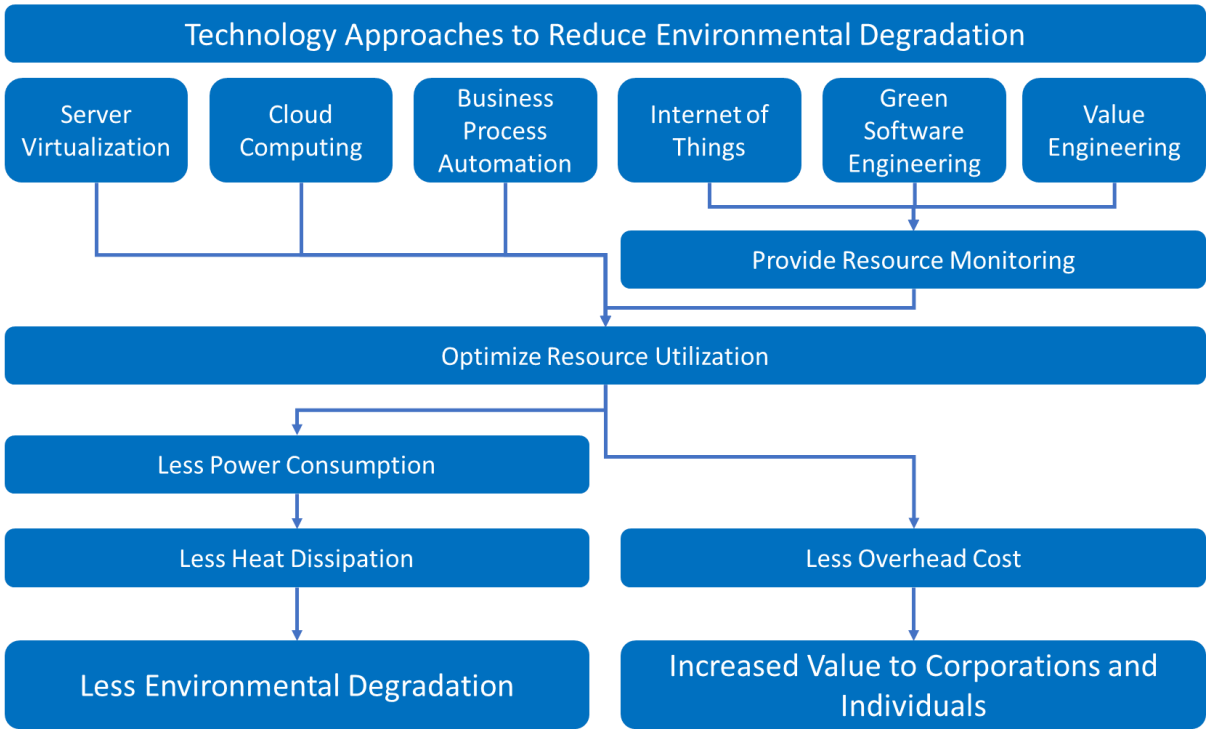

Figure 12: Conceptual Model of the Proposed Solution

6 Conclusion and Future Work

Information technology will no doubt play a significant role in environmental conservation. With the increasing rate of industrialization and the ever-changing technology, the rate of environmental pollution has increased significantly. This has led to the necessity for measures to be put in place to ensure that information technology does not continue causing the negative effects which harm humanity, but rather, be utilized in a smarter way to save resources and hence save the environment. Among the major forms of pollution is the emission of wasted energy, which is both expensive and harmful. In a bid to reduce all of this, green information technology approaches have been developed over time and are slowly being embraced by individuals, industries and, even governments. These approaches have proven to be not only beneficial in terms of helping secure the world from pollution, but also in terms of reducing operational costs in the said companies.

These green information technology practices include server visualization, cloud computing, business process automation, internet of things, green software engineering, and value engineering. The key concept of these techniques is to monitor and control resources utilization. Once resource consumption is optimized, businesses and individuals achieve the maximum outcomes with minimum cost. This cost can be defined financially, or through effort and time. Once cost is reduced, more value can be gained by both organizations and individuals enhancing people's quality of life.

This research has summarized the work of some projects that have been conducted by some researchers. This will, therefore, be a very good base for anyone who will want to do further research in relation to the viability of green technology projects. Based on the same principle of optimizing resources, future research can find more techniques to produce value to the environment, organizations, and individuals. In addition, future research can identify other key principles that can lead to reducing environmental degradation and enhance the quality of life of mankind.

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