A FRAMEWORK FOR MEASURING SUSTAINABLE GREEN INFORMATION TECHNOLOGY PRACTICES IN UNIVERSITIES OF SOUTH AFRICA

by

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DECLARATION

I <u>Ghebre Embaye Woldu</u> with the signature below declare that:

A Framework for measuring sustainable green Information Technology practices in universities of South Africa, I hereby submit for the degree of Doctor of Philosophy at the department of Information Technology in North-West University, is my own work and has not previously been submitted by me for the degree, at this or any other tertiary education institution. All the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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Signature of candidate   this 15th day of February, 2016

ACKNOWLEDGEMENT

ABSTRACT

Climate change and global warming are major challenges facing the environment today. The impact of climate change, together with pollution and the depletion of non-renewable natural resources, has raised an awareness to environmental sustainability. Even though there are many causes that affect climate change and global warming, technology affects the environment by far at a global scale. Technology is responsible for a minimum 2% of global greenhouse gas (GHG) emissions. Universities need to pause and reflect on the growing green technology importance, and why it will be important for future generations. The importance of green technology cannot be disregarded. Recognising the need to challenge the environmental impacts, universities have to address environmental issues through the scientific study of Environmental Management Information Systems (EMIS). Government supervisory constitutions and consumer action groups have promoted businesses and organisations to adopt green practices in dealing with the issue of environmental consequences. The concept of green IT has become the centre of policy debates for the well-being of the society through an awareness of design and technology.

This research outlines a framework for measuring sustainable green IT practices from an Information Systems and Technology perspective within South African tertiary institutions. Former research reveal how green ITs have significantly enabled and improved organisations in numerous significant ways. Nevertheless, these studies do not highlight the sustainable green IT practices particularly in universities of South Africa; this under-researched field of study is one of the research problems. Revisiting the environmental policies and creating a sustainable environment for South Africa's dynamic energy and human health impacts are worthy goals towards which to strive.

The framework is grounded in investigating the acquisition, utilisation and effectiveness of the operational carbon footprints and technological breakthroughs that will lead to a cleaner educational environment. In order to help universities in South Africa to adopt environmentally responsible practices, an in-depth qualitative research methodology was undertaken through interviews as survey instrument to gather data. The findings elucidate the necessity of ecological sustainability as a matter of fact to measure the performance of green IT implementation in universities. The result of the study exposed the role of the universities to reduce their environmental impact focused on bottom-line issues such as economic values, environmental issues, and social benefits. Some more practical

guidelines are provided to assist in greening the university and recognising the need to become greener. The research made an original contribution to the academic body of knowledge in creating a framework for measuring green IT practices, addressing the issue of energy efficiency, reducing of carbon footprint, adopting clean technology and managing the disposal of e-waste such as computers and IT-related devices in universities throughout South Africa.

Key words: (in alphabetical order):

Acquisition, carbon footprints, effectiveness, energy efficiency, environmental problems, environmental sustainability (ecological sustainability), e-waste disposal, framework, green Information Technology, greenhouse gas emissions, measure, practices, utilisation.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	Alternating current
ACM	Association for Computing Machinery
AMD	Advanced micro devices
ANOVA	Analysis of variance
APC	American Power Conversion
BFRs	Brominated flame retardants
BTU	British thermal unit
BYOD	Bring your own device
CCFL	Cold cathode fluorescent lamp
CCGrid	Cluster, cloud and grid
CCS	Carbon capture and sequestration
CFL	Compact fluorescent light
CRT	Cathode ray tube
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Corporate social responsibility
CVS	Computer vision syndromes
DC	Direct current
DCIE	Data centres infrastructure efficiency
DESCO	Development of engineering surface coatings obtained
DVD	Digital versatile disc (Digital video disc)
EBSCO	Elton B. Stephens Co.
EMAS	Eco-management and audit scheme
EMIS	Environmental management information systems
EPA	Environmental Protection Agency
EPEAT	Electronics products environmental assessment tool
FAO	Food and Agriculture Organisation of the United Nations
FSC	Forest Stewardship Council

GBI	Green building initiatives
GG-SD	Green growth and sustainable development
GHG	Greenhouse gas
GSA	Geological Society of America
GTM	Grounded theory method
HP	Hewlett Packard
Ibidem	In the same place (book, etc.)
IBM	International Business Machines
ICCT	International Council on Clean Transportation
ICT	Information communication and technology
IEA	International Energy Agency
IEASA	International Education Association of South Africa
IEEE	Institute of Electrical and Electronics Engineers
IPCC	Intergovernmental Panel on Climate Change
IS	Information systems
ISO	International Organisation for Standardisation
IT	Information technology
JETRO	The Japan External Trade Organization
KW	Kilowatt
LAN	Local Access Network
LCD	Liquid crystal display
LED	Light-emitting diode
Met Office	Meteorological Office
MHEIs	Merged higher education institutions
MODIS	Moderate resolution imaging spectroradiometer
MSG	Meteosat second generations
NAS	National Academies of Science
NEXUS	Research support and knowledge networking databases
NGO	Non-governmental organisation

NRC	National Research Council
NRF	National Research Foundation
NWU	North-West University
OECD	Organisation for Economic Co-operation and Development
OLED	Organic light-emitting diode
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PH	Potentiometric hydrogen
PVC	Polyvinyl chloride
PWM	Pulse width modulation
RF	Radio frequency
RoHS	Restriction of hazardous wastes
SABINET	South African Bibliographic and Information Network
SD	Sustainable development
SPARC	Scalable processor architecture
SPSS	Statistical package for the social sciences
SSO	Solid-state drive
TCO	Tjänstemännens Central Organisation
TWh/a	Terawatt hours per anum
UKZN	University of KwaZulu-Natal
UN-OHRLLS	Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
UNEP	The United Nations Environmental Programme
UP	University of Pretoria
UPS	Uninterruptible power supply
WAMIS	Wide area monitoring information system
WCED	The World Commission on Environment and Development
Wits	University of Witwatersrand
WWF	World Wildlife Fund

CHAPTER 1

GENERAL OVERVIEW OF STUDY

1.1 Introduction

Human beings are dependent upon the benefits of the earth's environment as well as its ecosystems. In as much as the population depends on the environment, technology offers a future of enriched communication facilities, human solidarity, improvement to standards of living and necessities to adapt and mitigate climate change (Organisation for Economic Co-operation and Development – OECD, 2011). On one hand, the use of technology contributes to an increased human impact such as pollution, excess energy and electronic waste that affects the environment negatively, and challenges the survival of living things in general (Murugesan, 2013, Molla, 2009). On the other, the prime significance of the environment and its care call for prudent utilisation of such technologies.

A university as an organisation, is responsible for sustainable educational materials. It provides students and lecturers with the information they need to understand fundamental environmental issues and to take measures that safeguard the earth from environmental depletion and damage (Ahmad *et al*., 2013). Wals and Jickling (2002), suggest that education for sustainable development promotes competencies such as critical thinking, and they contemplate future developments that are pivoted on collaborative decision-making techniques. Sustainable green IT can make a substantial contribution to education in achieving a better world through the elimination of irreversible damage to the biosphere, generally minimizing the environmental impact and giving an advantage over other institutions in generating positive economic value (Ahmad *et al.,* 2013).

The general overview of this chapter is to set the background for the thesis by clarifying what the study was concerned about, to whom it is applicable, where it took place, how it was done, and the reason why it was conducted. Following this introduction, the background and context of the study is explained, the problem definition is stated and the overall research objectives are presented. Subsequently, the research design and methodology, the obstacles and the result that can be expected of the research are discussed. Afterwards, the importance and significance of the study is illustrated, the

research layout is justified, and the limitations of the study are revealed. Finally, the research becomes complete with the presentation of a chapter summary.

1.2 Glossary of key concepts

This section provides definitions of many terms used to conduct qualitative research for measuring sustainable green IT practices in universities of South Africa.

Anthropogenic:	(e.g. a greenhouse gas) emitted or created by human activity (British Geological Survey, n.d.).
Biodegradable:	Capable of being decomposed by bacteria or other living organisms without causing harm to the environment (BusinnessDictionary.com, 2013).
Biomass:	Renewable energy source from a living or recently living plant (e.g. a plant material that produces steam) and animal materials (e.g. animal fossil) which can be used as fuel. It is, in short, carbon-based mixtures of organic molecules (Yourdictionary.com, n.d.).
Biosphere:	Part of the Earth's surface and atmosphere that contains the sum of all ecosystems, and contains all living organisms and what supports them; soil, subsurface water, bodies of water and air and includes the hydrosphere and lithosphere (BusinnessDictionary.com, 2013).
Carbon footprint:	A term used to describe the total greenhouse gas (GHG) emissions caused by an organisation, event, product or person (EPA, 2013c; Herrmann *et al*., 2012).
Climate change:	A long-term shift in weather conditions, for instance, major changes in temperature, rainfall, snow, or wind patterns over periods longer than ten years (EPA, 2013a).
Conservation:	Protection from injury, decay, waste or loss, normally applied to natural resources and energy (Dictionary.reference.com, n.d.).
Consumption:	Use of goods and services until disposal by households (Britannica.com., n.d.).
Deforestation:	The cutting down of trees, transforming a forest into cleared land (Vocabulary.com, n.d.).
Disposal, interchangeable with discard:	The action or process of throwing away or getting rid of (OxfordDictionaries.com, n.d.).
Eco-sustainability, interchangeable with eco-friendly,	A business's ability to deliver competitively priced goods and services, while progressively reducing ecological impacts (Molla, 2009; Watson *et al.,* 2010).

eco-efficiency and environment friendly or nature friendly:	
Ecology:	Derived from Greek: "οἶκος" meanings "house" or "living relations"; and "λογία" meanings "study of"; it is the scientific study of the interactions of living things with each other and their physical environment (Begon *et al.,* 2006).
Electronic waste (e-waste):	A generic term including various forms of electrical and electronic equipment that are old, end-of-life electronic appliances that have ceased to be of any value to their proprietors (Bandyopadhyay, 2008)
Emissions:	Substances discharged into the air (OxfordDictionaries.com, n.d.).
Energy, interchangeable with power:	A power derived from the utilization of physical or chemical resources (Ibidem).
Geothermal:	Refers to clean and sustainable energy derived from the heat in the interior of the earth (Renewable-energy-world.com, n.d.).
Green IT, interchangeable with green computing, or sustainable ICT:	The application of environmental sustainability, specifically throughout the Information Technology (IT) life cycle (Molla *et al.,* 2011). It is the study and practice of re-designing, manufacturing, using and disposing of computers, servers and associated subsystems such as monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal or no impact on the environment (Murugesan, 2008), with a focus on e-waste minimisation and energy-efficiency maximisation (Watson *et al.,* 2008).
Greenhouse gas (GHG):	A gas that contributes to the greenhouse effect by absorbing infra-red radiation (IPCC, 2007b).
Green washing:	Deceptive promotion of products and services as green by an organisation so as to present an environmentally responsible public image (Whatis.com, n.d.).
Global warming:	A type of climate change characterised by an average increase in the temperature of the atmosphere close to the Earth's surface (EPA, 2013a)
Hazardous waste, interchangeable with toxin:	Waste that is dangerous or potentially harmful to our health or the environment. It can be liquids, solids, gases or sludges (Sabha, 2011).
Hydropower or hydroelectric power:	The word "hydro", meaning "water" is derived from the Greek root "ύδωρ". It is a renewable energy generated from the energy of falling water and running water (Edfenergy.com, n.d.).

Life cycle assessment (LCA):	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. [ISO 14040]
Non-renewable energy (vs. renewable energy):	Energy that does not exist freely in nature but took millions of years to form and which will run out at a certain stage, such as energy from fossil fuels (coal, crude oil, natural gas) propane and uranium (Eschooltoday.com, n.d.).
Non-renewable resource (vs. renewable resource):	A resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption (Investopedia.com, n.d.).
Obsolete:	Refers to outdated computer hardware, software, services or practices that are no longer used, even if they are in good working order. Actually, a technology becomes obsolete when replaced by a newer or better technology (Techopedia.com, n.d.).
Pollution:	An introduction into the environment of a substance which has harmful or poisonous effects (EPA, 2013c).
Products:	Substances that are manufactured or refined for sale (Dictionary.com, n.d.).
Recycling:	The process of extracting and reusing useful substances found in waste, or conversion of waste into reusable material (Thefreedictionary.com, n.d.).
Renewable energy (vs. non-renewable energy):	Energy that can be replenished easily over time by some natural process, such as solar, wind, hydro, geothermal and biofuel energy (Yourdictionary.com, n.d.).
Renewable resource (vs. non-renewable resource):	Relates to an environmental resource that can be replenished over time by some natural process; these include fossil fuels such as oil, coal, and gas (Ibidem).
Sustainable development:	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on the Environment & Development, 1987).

1.3 Background and context

Green Information Technology (IT) started as early as 1992, when the Environmental Protection Agency (EPA) created Energy Star, which is a labelling programme aimed at supporting organisations and individuals to save money and protect climate change through superior energy efficiency (Weems, 2010). Green IT was initiated to ensure smart decisions that protect investments and safeguard the health and security of societies, economies and infrastructure from the impact of severe weather contributing to climate

change (Gingichashvili, 2007). EPA promotes a number of factors that contribute to cleaner technology by proposing carbon pollution standards for power stations and formulating policies and guidelines by which the business sectors and organisations could possibly reduce greenhouse gases and become global market leaders in addressing the challenge of climate change (Herrmann *et al.,* 2012).

The term green IT is interchangeably known as sustainable Information Communication and Technology (ICT) or ICT for sustainability, environmental technology (envirotech), Environmental Management Information System (EMIS), green technology (green tech), as well as clean technology (clean tech). Sustainable green IT covers a range of subjects: energy savings or conservation, energy efficiency and renewable energy that generate electric power from other sources of primary energy, the reduction of a carbon footprint and coal consumption, actively dealing with environmentally sustainable infrastructure design and e-waste disposal (Gingichashvili, 2007; Molla, *et al.,* 2009; Murugesan, 2010; Porter & Kramer, 2006). Ultimately, green IT or environmental technology deals with subjects that can potentially cause dangerous climate change and global warming. Its main emphasis lies in realizing and encouraging new ways of reducing pollution, implementing higher efficiency and alternative power generation systems, discovering alternative data servers, and manufacturing computers that are recyclable, as well as the use of less hazardous materials in this technological revolution (Murugesan, 2013).

The term "sustainable" connotes a complete openness to green IT. The word is derived from the Latin word "sustinere" or "tenere", which means "to hold on" or to maintain or capable of being maintained" (Dictionary.com, n.d), "to keep up, especially without interruption, diminution, flagging" or "to prolong" (Webster's New International Dictionary, 1986). But sustainability in relation to green IT is more meaningful than just "to keep" or "to maintain" or live a life on this planet. Sustainable green IT refers to environmentally sustainable computing or sustainable IT, evolving product-delivery mechanisms, manufacturing, operating methods, such as waste management practices (materials recycling, waste exchange), better utilisation of IT software and hardware that conserve energy and natural resources, minimising the environmental load of human activities, and protecting the natural environment (Molla, 2009).

Sustainable green IT encompasses the adoption of computer and information systems and IT application patterns for green optimisation, as well as green maturity models for virtualization and practices in an efficient environmentally responsible way (Murugesan,

2013). It entails planning and investing in a technology infrastructure that serves the needs of today as well as the needs of the future generation, while conserving resources and saving money. Molla *et al.* (2011), in agreement with Lamb (2009) define sustainable green IT as the way and practice of using computing resources efficiently, and as an activity of treating the environment with responsibility. "Sustainable green IT" is generally understood to mean "friendly to the environment, by conserving natural resources and assessing relevant energy and material inputs."

Though the terms "green" and "sustainable" are used interchangeably, there are quite a few differences between them. Samson (2007) distinguishes between "green" versus "sustainable" technology. According to him, "green" generally means environmentally friendly and energy efficient, whereas "sustainable" reflects planning and investing in a technology infrastructure that serves the need of today and the future in helping to save money on wasted resources, for instance, energy and paper. In general, sustainable products and activities are subject to a higher standard of performance of "future" factors.

Sustainability is therefore a much more comprehensive term embracing the implications of products and services used over a longer period of time, and considering social and financial impacts. Jenkin *et al.* (2011) highlight environmental sustainability as the development that considers needs and aspirations of the present without compromising the ability of future generations to meet their own requirements. To Molla (2009) green is the starting point towards a sustainable journey, while sustainable is a journey of improving technology rather than aiming at a destination. Murugesan (2013) points out that sustainable IT is a much broader research area spanning the spectrum of Computer Science and engineering, electrical engineering, buildings, products and supply chains as well as other engineering disciplines that directly and indirectly affect the environment. In general, Murugesan (2013) argues that sustainable products and activities are subject to a higher standard of performance because of "future" factors in this wider spectrum.

1.4 Research statement and problem

In grounded theory it is important to deal with research propositions, but not research hypotheses (Glaser & Strauss, 1967). Propositions are included together with generalised research questions. It is a theory developed from theories in previous literature by refining them into a declarative statement of a concept for empirical testing. The problem statement can be present as research questions or propositions (Mavetera, 2011). When constructing

a theory or concepts or values, a set of statements are developed, and from these statements, theoretical formulations and propositions are established. Eventually, from these propositions, hypotheses are derived and tested (Mavetera, 2011).

In the past, organisations paid little attention to environmental aspects of the equipment and resources they used, or the way resources were consumed and disposed of (UNEP, 2010; UNEP, 2011). Today, sustainability issues are becoming an important consideration in transforming the world's economies, industries, organisations, education and business models (Gingichashvili, 2007). Understanding the impact and benefits (for instance securing cost savings) of implementing a green IT strategy are getting increasingly essential for improving the quality, efficiency and effectiveness of education and training systems in South Africa.

Green ITs are playing an increasing role in the environment, from the local to the global level, among government and private and civil society stakeholders (Melville, 2010; Watson, *et al.,* 2008). Green ITs have permeated socio-economic development, and this niche enables the development of new skills, competitiveness and growth, particularly in developing nations to better address to the challenges posed by climate change. The capacity of green IT to mitigate the harmful effects of climate change imposes a responsibility on policy makers, and indeed all stakeholders of the Information Society to promote technology as an effective tool to combat climate change (Murugesan, 2008; Murugesan, 2010).

The first Green Growth and Sustainable Development Forum (GG-SD, 2012) occurred to challenge complex issues, and in most cases required cross-sectoral and multi-disciplinary responses on: 1) how to reduce coal consumption, overpopulation and use of natural resources; 2) the best way to remove perverse subsidies; 3) how the poor may be protected or compensated, the possible regressive impact of policy reforms, and 4) what the synergies between green growth and poverty reduction are that has not been accomplished on the route to sustainable development since the Rio Earth Summit in 1992.

Growth over the previous twenty years has not been sufficiently comprehensive and has come at a price to the environment (GG-SD, 2012). During the Rio Earth Summit in 1992, roughly 250 participants from different countries, including South Africa, attended the forum. As identified by King (2013), to achieve the growth discussions that took place, business sectors, investors and shareholders who were gathered from across the world used

the opportunity to exchange experiences and best practices with the management of natural resources in order to foster growth and achieve sustainable development.

South Africa, like other developing countries, is susceptible to the adverse effects resulting from the incessant alteration of climate and weather patterns, from changes in temperature and seasonality, to the occurrence of more frequent and intense weather-related and technology-related events (Kyoto Protocol, 1997). The degree of these impacts demands the adoption of novel approaches that would allow South Africa to withstand, recover and adapt to change, especially through the contribution of universities in engaging with society in meaningful and mutual ways to benefit each other. As any other organisation, universities have been required to optimise their roles as key players within society to reduce their environmental footprint and measure progress.

The Green Paper of South Africa (1996) was intended to identify the subjects which need to be addressed when the White Paper was formulated. This Green Paper looks at initiating a broad framework for an integrated and general approach to environmental management in all areas of government. Some of the aspects are improved pollution and waste control, focusing on people and their participation in environmental decision making, developing an improved system of governance and achieving sustainable development. The Green Paper specifies that there are many capacities which the government needs to address. Yet, there are issues which have been left out of the Green Paper and require further refinement and debate too. For instance, the Green Paper of 1996 does not present detailed policy proposals for the many specific issues involved in achieving effective environmental management and a sustainable use of natural resources. It rather proposes a broad framework of principles, processes, structures and mechanisms to integrate environmental governance that would enable the development of policy, strategy and action.

McCabe (2009) affirms that the adoption of sustainable green IT is firmly based on the strategy of mini, medium and large size progressive market companies. He illustrates that increased profitability, reduced operating costs and improved brand reputation together with growing consumer demand for sustainable products and government policies are geared towards the acceptance of sustainable business practices in every industry. Businesses are increasingly dependent on technology such as personal computers, notebooks, palmtops, tablets, iPod, iPad, iPhone and smart phones on a daily basis, connected to servers running 24 hours per day.

Computers, used or owned by students, staff and support staff are found in campus offices, dormitories, printing presses and classrooms. This study unveils how many desktops, laptop computers, monitors, printers, scanners, faxes, communication devices and servers are used for administrative, management and academic research in the universities. All of this equipment constitute a source of energy use and greenhouse gas emissions, including e-waste dangers. The use and disposal of such equipment takes centre stage (O'Connor & Meil, 2012). In addition, computers generate heat that takes as much energy to cool down as it takes to generate it (Rowe, 2011). Even worse, as specified by Mill (2013), electronics account for 10% of the world's heat production; and leaves a surprisingly large energy footprint of the digital economy, especially in the USA and China, which are the world's major producers of electronic waste.

Information processing has been comprehensively integrated into daily objects and activities. Technology assists businesses to plan and implement activities that meet the needs of the stakeholder. "Sustainable green IT" is the latest catchword, and green washing should not be thrown around by various academic institutions, organisations and industries. IT professionals and the IT industry are now entitled to use IT systems and their work practices to make that world greener and to harness the power of IT to address the increasing environmental and social impact (Murugesan, 2013).

Sustainable green IT has become innovative and has received attention on creating a framework in which technology and environments, IT sectors and organisations meet together in commonalities. Helping universities to meet their sustainable objectives faster and improve the accuracy of reporting to the students and staff is becoming a core part of IT managers' planning. Environmental changes and global warming, the depletion of natural resources, and a reliance on IT are compelling green IT strategy to become a necessity. Murugesan (2013) states that many industries and organisations have turned their attention to realizing how sustainable green IT can benefit society in reducing costs and lowering greenhouse gas (GHG) emissions and carbon footprint from industrial manufacturing and organisational practices. He also agrees that organisations can enhance their reputation while controlling costs through lower energy bills and automated information management processes by achieving their sustainability goals.

Molla *et al.* (2009), in supporting Murugesan (2008), consider the environmental problems as being global and IT being responsible for a much higher percentage of the GHG footprint of that environment. The demand for IT professionals as part of resolving eco-

sustainability issues is a necessity to avoid potentially disastrous consequences and environmental problems as the world's climate warms up. Businesses and governments are trying to balance growth with environmental risks using innovative IT ways to address environmental problems. IT is seen both as a solution and a problem for environmental sustainability (Molla & Abareshi, 2012). A significant part of emissions, electrical consummations and hazardous waste comes from the inefficient use of ICT equipment and too little consideration of environmental effects when manufacturing, buying or replacing ICT equipment (Murugesan, 2008).

The issue of e-waste raises concerns about resource efficiency and also the immediate concerns of the risks to humans and the environment. According to The Guardian (2013), fifty million tonnes of e-waste was generated nationwide every day at that stage, which contributed to the rate of pollution of about 7 kg for every person on the planet. The electronic digital age made an unprecedented impact on human society.

E-waste contains toxic substances such as lead (Pb), mercury (Hg), cadmium (Cd), and lithium (Li). These toxic materials can be released upon disposal, posing a threat to human health and the environment (The University of Illinois, 2009). Inconsistencies in student and staff safety and environmental protection pose potential liability concerns for those sending electronics to recycling facilities, especially if these facilities are situated in developing countries. However, e-waste also contains precious metals such as gold (Au) and silver (Ag), which offer opportunities via recycling for economic extraction. Precious metals contribute well over 70% of the metal-related value of mobile phones, calculators and printed circuit board scraps. In other items such as TV boards and DVD players, they still contribute about 40% of the value (The University of Illinois, 2009).

Current green buildings demand a new approach of complex relationships between the natural and the built environments in a way that homes, office buildings, schools and universities support the health and wellness of individuals who reside and work there (Conn, 2011). Traditional buildings have a lot of finishing products which usually consist of ingredients such as binders (mediums), solvents (thinners), colouring agents and additives which are not friendly to the environment. All these affect human beings negatively in areas such as visual appearance, nausea, headaches and damages to the liver or kidneys. Whilst natural building materials such as clay, lime and wood ensure a positive impact on air pollution by being non-toxic; regrettably, not all natural finishes are as safe as they claim to be. Although they may claim to be green infrastructures, they may also

toxic to the environment as well as to human health and safety (Conn, 2011). Going green in infrastructure and manufacture is one of the environmental protection practices that supports and promotes the use of processes that are environmentally-friendly, responsible and resource-efficient throughout.

Leading transformation to green IT demands that universities reduce their energy consumption, reduce operational footprints, save on the cost of electricity bills, extend their budget and be eco-friendly. Universities can also benefit from having programmes such as IBM's Big Green Innovations. IBM contributes intelligent tools that help education improve competitive agility and maintain a competitive edge, targeted at helping education and businesses design more energy-efficient data centres that house servers, data storage and network infrastructure. IBM also buys back and disposes of used computer systems from higher education institutions. In doing so, the company helps them understand that the amount of energy consumed is central to decisions concerning the use and conservation of energy to mitigate the environmental impact (Kumar, 2011).

Williams (2013) affirms that organisations face a tough challenge of meeting demands such as increasing demands for traveling with limited resources. To overcome these challenges, organisations are looking at cloud-based services that offer improved benefits over business performance, including reduced cost, a commitment to quality and easy maintenance and re-provisioning of resources, and telecommuting that saves the environment and thereby increases profits. Mell and Grance (2011) highlight that cloud computing offers several advantages by allowing users to use services that include infrastructure, servers, programmes, applications and storage space and network at a nominal fee. As these services are created and offered by the cloud service provider, it is not necessary to purchase additional infrastructure for use at one's own premises.

The 14th Annual IEEE/ACM International Symposium (2014) in Cluster, Cloud and Grid Computing (CCGrid) reported that the rapid improvement in network architecture, operating systems and middleware technologies is leading to new advances and platforms for computing, ranging from clusters and grids to clouds and datacentres. Cloud computing is a model for enabling pervasive, convenient, on-demand network access to a shared pool of configurable computing resources. Similarly to that point of view, Mell and Grance (2011) define cloud computing as a handy pay-per-use model for enabling on-demand-access to reliable and configurable resources that can be quickly provisioned and released.

There are currently so many mobile phones in use; in fact, some students and academic staff members might have more than one mobile for each person. Millions of mobile phones thrown away annually are being leaked into the environment, causing implications to society; furthermore, they are not exactly biodegradable. Recycling mobile phones can retrieve valuable resources such as copper and other metals and keep them from filling up landfills (Sabha, 2011). Viswanathan (2011) outlines mobile phone brands that also offer an advantage of cloud computing because many users like to back up their mobile phone data online, though they are usually bound to their own operating systems.

Harris (2012) articulates the view that with software such as Google Apps, all the documents, emails, calendars and sites automatically save in order to enable users to work securely in the cloud, no matter where the person is and what devices someone uses. Every user can be productive from anywhere in his/her office, using any device with an online connection. Google Apps supports reduce both the company's overall expenses and its environmental impact. It is a suite of Google application that lets businesses, schools and higher education institutions use a variety of Google products powered by Google's energy-efficient data centres, so it uses less energy and is more carbon-intensive than on-premise servers. In addition to that, collaborative tools such as video chat and shared documents help make individuals comfortable and reduce extraneous employee travel, office materials and the overall environmental footprint (Harris, 2012).

Environmental sustainability problems are not problems of technology only; they embrace a wider area such as industry, biology, ecology, chemistry, geology and sociology. Though technology has liberated human beings from hunger, deprivation and insecurity, it has also generated numerous side effects; it consumes more resources and power. Moreover, electrical and electronic equipment contain different hazardous materials which are harmful to human health and the environment if not disposed of carefully. The overall problem of technology has been contributing to environmental problems during the manufacturing and disposal of products, which most people do not realize (Molla, 2009). Additionally, IT hardware and infrastructure pose severe environmental problems by consuming significant amounts of electricity and contributing to greenhouse gas emissions (Murugesan, 2008).

A university as an organisation needs to address the sustainable green IT to adequately prepare students and lecturers for professional practice. Managing the environmental impacts and benefits obtained from sustainable green IT is a strategic imperative for every

organisation in the 21st century. The world is too compactly populated to escape the effects of greenhouse gas emissions, electronic waste deployment and toxic production methods (Murugesan, 2013). Reducing carbon dioxide and other greenhouse gas pollution is not only required by the government and IT professionals, but it is also critically important for the protection of the health status of the South African public at large and students as well as academic staff in particular, as well as the environment upon which they depend.

Environmental sustainability is a persisting problem and it is an unavoidable issue for conversation. Universities need to address and re-assess this urgent matter in the spirit of creating awareness of the sustainable green IT for a healthy environment and the effective use of technologies, and of course, to adequately prepare learners and teachers for proficient practice. The research area of green IT is blossoming, as both academics and practitioners look for innovative ways of using systems to help achieve environmental sustainability objectives (Melville, 2010).

Students and academic staff members can promote environmental sustainability by reducing their carbon footprint to neutral during their lifetime, recycling wastes alongside landfills or waste bins, raising continuous awareness through campaigns and competitions, as well as by saving energy and water. These types of practices and principles provide higher education institutions with the opportunity for hands-on learning and demonstrate the interconnectedness to the built environment and natural systems.

The problems from contemporary human practices defined above constitute a threat to human existence. A commitment to generating positive economic values for students, staff members and society is necessary to deal with the following general problems: managing e-waste disposal, avoiding or mitigating threats of the generation of greenhouse gas emissions, determining the environmental and health impacts of IT-related products and redesigning alternative solutions that improve efficiency in products, process and usages.

Based on contemporary human practices and general arguments explained above, the preliminary literature search has revealed that not much research has been done to investigate the educational response to climate change and environmental care. The above-mentioned problem definitions can be broken down into smaller parts and rephrased to give an abstract statement as the following general problems and sub-problems that can be individually subjected to empirical investigations:

1.4.1 The overall general problems

1. Organisations which currently own a huge number of computers, other electronic products and IT infrastructure to dispose of e-waste, as IT hardware pose severe environmental problems, both during production and disposal. As new products are purchased, obsolete products are stored or discarded to make IT environmentally friendly and secure the implementation of strategies in relation to e-waste disposal management.

2. The policy and practice adopted should help reduce the generation of greenhouse gas (GHG) emissions, pollution due to a large carbon footprint and energy consumption, as well as other related side-effects throughout the associated upstream and downstream processes in order to assist clean energy and low-carbon economy.

3. Technology is not inherently good or bad; the outcome depends on how it is used. Yet IT is not known as part of the problem or solution to mitigate the effects of technologies; other related side-effects of current and emerging technologies that are bound to go up further in the future and continue to be an important issue for several years have not yet been identified and implemented.

4. It is not yet determined how the adoption of green IT practice affects the start-up cost of implementing the rapid technological changes that offers considerable under-powered (energy-saving) benefits for embracing green IT products, applications, services, policies, operations and practices. Several companies are convinced that the more environment-friendly they become, the more the effort will erode their competitiveness.

1.4.2 Minor/secondary problems

The researcher firstly applied the conceptual matrix framework adopted from Klopper and Lubbe (2011) to state the alignment for the problem-research questions in order to ensure that the minor/secondary problems that were identified in the problem definitions were correctly associated with the research questions and, secondly, to secure viable empirical results and to present a concept-centric rather than an author-centric literature review.

Organising literature concept-centred on a comparative matrix protects the researcher against ignorant assumptions about the research theme at a stage of lack of knowledge

about the topic under investigation. A well-designed research project provides a powerful, integrated research methodology and analysis to achieve traction, coherence, and progression and closure in problem-solution-oriented research (Klopper & Lubbe, 2011).

General problem	Minor/secondary research problems	Minor/secondary research questions
1. Organisations which currently own a huge number of computers, other electronic products and IT infrastructure to dispose of e-waste, as IT hardware pose severe environmental problems, both during production and disposal. As new products are purchased, obsolete products are stored or discarded to make IT environmentally friendly and secure the implementation of strategies in relation to e-waste disposal management.	Approaches and strategies that can be implemented in organisations to reduce, re-use (refurbish or repair), recycle and remanufacture items in order to improve the sustainability of an e-waste management system. **Lesser research problems** The following issues have not been assessed and evaluated: 1. Ensure better management of waste disposal. 2. Buy eco-friendly range of products aimed at reducing e-waste. 3. Provide "cradle to grave" hazardous waste management authorities to identify and quantify the rate of e-waste flows. 4. Develop e-waste regulations that improve compliance and decision making. 5. Convert the challenges of e-waste into opportunities.	What approaches and strategies can be implemented in organisations to reduce, re-use (refurbish or repair) recycle and remanufacture items in order to improve the sustainability of an e-waste management system? **Lesser research questions** These are the possible lesser questions that can be raised from the secondary problems: 1. How can better management of waste disposal be ensured in order to save waste (energy, time, resources and cost)? 2. What would the scenario be in buying eco-friendly range of IT products aimed at reducing the e-waste to establish environmentally sound facilities and technologies? 3. Where are the obsolete computers of universities placed, resold, donated or exported? 4. How should South African universities develop e-waste regulations that would improve compliance and conformity to legislation? 5. What could the environmental, economic and social consequences of a potable handling of e-waste be?

2. The policy and practice adopted should help reduce the generation of greenhouse gas (GHG) emission, carbon footprint and energy consumption and other related side effects throughout the upstream and downstream processes associated with the production, in order to assist clean-energy and low-carbon economy	Reduce the generation of greenhouse gas (GHG) emission, carbon footprint and energy consumption as well as other related side-effects to minimise the use of energy throughout the life cycle, including the redesign of alternative solutions. **Lesser research problems** The following issues have not been identified and implemented: 1. Reduce offices' operational footprint and design buildings to aid cooling in order to assist clean-energy and low-carbon economy. 2. The IT equipment and systems used need to reduce the operational carbon impact of high performance computing (HPC) and the use of significant resources. 3. Launch paperless statements such as e-payment and e-statement initiatives to conserve natural resources, and use toner cartridge recycling programmes that eliminate significant solid waste and the carbon footprint. 4. Determine the choice of IT-related products and services that reduce the consumption of	What measures should be used to reduce the generation of greenhouse gas (GHG) emission, carbon footprint and energy consumption as well as other related side-effects to minimise the use of energy throughout the life cycle, including the redesign of alternative solutions? **Lesser research questions** These are the possible lesser questions that can be raised from the secondary problems: 1. How do you describe the quality of the buildings, offices, classrooms and computer LANs in supporting the health and wellness of individuals who reside there, protecting these from excessive moisture, and improve comfort in warm weather by increasing air movement and removing heat? 2. What techniques can be used to improve the sustainable re-designing of mechanic (metal, plastic, paper) and electro mechanic parts (connectors, cables, fans) in a manner that enhances the carbon impact of high performance computing (HPC)? 3. What approach could be launched to manage the optimisation of printing and digital solutions of universities in South Africa in supporting paperless initiatives, and the purchasing of FSC certified recycled copy paper?

	electricity and generation of carbon footprints.	
	5. Use ultimate paper reduction solutions through collaborative learning tools such as e-mailing documents to other people; faxing directly from the computer to eliminate the need for hard copies; reviewing and modifying documents on the screen and using Print Preview to save costs of products and conserve natural resources.	4. What type of management can possibly be implemented to increase material and energy efficiency of the IT infrastructure of the universities (with cloud computing, server visualization and consolidation, storage consolidation and desktop visualization) and business activity (remote conferencing, telecommuting, printer consolidation and PC power management)?
	6. Minimise emissions, effluents and accidents and use non-renewable forms of energy.	5. How should the students and lecturers interact with researchable issues, assignments and project submissions in terms of collaborative learning tools?
	7. Buy products that qualify for an Energy Star 4.0 rating and above.	6. What alternative renewable energy source could universities use to significantly reduce power demand and carbon footprints?
	8. Use improved energy-efficiency sources for computing workstations, servers, networks and data centres.	7. Why do users need to buy the equipment labelled with energy-star-qualified products?
	9. Replace down equipment that are energy-intensive and contain toxic substances (desktops vs. laptops, CRT vs. LCD, laser printer vs. other printers.	8. How does telecommuting via cloud computing, workstations, data centre and networks offer energy-efficient advantages and reduce electricity expenses?
	10. Set up a method of guidelines and best practices of energy or power management.	9. What are the criteria of purchasing programmes and resources to make the organisation both greener, cheaper and lighter on energy use and other health-related problems?

		10. What methods do users practice during the extended period of inactivity (power down, or background screen mode, hibernation mode, or sleep mode?)
3. Technology is not inherently good or bad, the outcome depends on how it is used. Yet, IT is not known as part of the problem or solution to mitigate the effects of technologies; other related side-effects of current technologies and emerging technologies that are bound to grow rapidly in future and continue to be an important issue for several years have not yet been identified and implemented.	Focus on the optimisation of sustainable IT resources in the acquisition, utilisation and effectiveness of new technology to help reduce the environmental impact. **Lesser research problems** The following issues have not been identified and implemented: 1. Designing technological platforms capable of delivering the required diverse and multi-disciplinary skilled research and production workforces. 2. Considering input costs in terms of regulations, energy use, storage and disposal. 3. Using web conferencing, virtual labs to speed up dissemination of scientific results through distance knowledge sharing and exchanging instead of traveling to meetings. 4. Assessing and improving a broad range of	What is the key environmental impact arising from IT that has to be addressed and planned to reduce the environmental problems of IT and create a sustainable environment in the acquisition, utilisation and effectiveness of new technology to lessen and eliminate environmental impact? **Lesser research questions** These are the possible lesser questions that can be raised from the secondary problems: 1. How does the technology used in organisations improve knowledge and technology-transfer mechanisms to the students, staff and society? 2. What are the IT sector's strategies in addressing environmental issues that satisfy stakeholder expectations on social issues, environmental performance and daily environmental risks? 3. How are telecommuting, web conferencing and virtual LANs practised in the universities to support staff to interact in distance facilities instead of travelling to meeting and use transport that generates carbon emission? 4. What are the overall challenges in developing and driving

	challenges in developing and driving the overall sustainable green IT strategies and programmes.	sustainable green IT strategies and programs?
4. The effect of the adoption of green IT practice on the start-up cost in implementing rapid technology change that offer considerably lower power (energy-saving) and benefits for embracing green IT products, applications, services, policies and practices has not yet been determined. Even so, several companies are convinced that the more environment-friendly they become, the more the effort will erode their competitiveness	As the result of sustainable green information technology, there will usually be some kind of added cost when old equipment is discarded and replaced by new and efficient technology. Thus, an assessment of positive performance on profitability and reliability of green IT is imperative. **Lesser research problems** The following issues have not been identified and implemented: 1. Green IT contribution to the organisation in lowering the cost of input and output. 2. Vibrant measurable advantage and objectives for green IT to increase students and staff productivity by creating healthier working environment.	How will technology affect the start-up cost in implementing rapid green IT change that offer considerably lower power (energy-saving) benefits for adopting green IT products, applications, services, policies and practices? **Lesser research questions** These are the possible lesser questions that can be raised from the secondary problems: 1. How do universities in South Africa recognize green IT as a significant contributor to their overall sustainability strategy? 2. What vibrant measurable advantage and objectives are available for green IT to increase student and staff productivity by creating a healthier working environment?

Table 1-1*: The problem research question alignment matrix for solving the issue of sustainable green IT, adopted from Klopper & Lubbe (2011)*

1.5 Research motivations and objectives of the study

Universities are immensely important shaping both national and provincial governments, and maintaining world-class research and learning facilities provided to the citizens of a country. The special issue magazine, *Voices rises* reported (2013) that Nelson Mandela stated in his Nobel Peace Prize laureate, "Education is the most powerful weapon which you can use to change the world." Based on this statement, no country can really develop sustainable environmental management, unless its citizens are really aware and educated. Therefore, learning environmental education can transform the young generation into a better society at large, a society with people aware of their rights and duties and the care of environmental stewardship. Universities have a key role to play in addressing this challenge and to renew their commitment to a greener higher education sector. Thus, teaching and learning are vital to inspire and educate the next generation of decision makers, the business sector and South African citizens, and to equip them with the skills and knowledge to deal with ways to tackle climate change.

The researcher believes that because of a deeper understanding and concern of the sustainable environment issue, the more highly educated persons are more likely to help and solve the very real problems of environmental degradation and devastation, in what they know, in what they invent, in what they do and what they buy, rather than with simple actions or practices such as turning off lights to reduce (solve?) the consumption of electricity. The higher education institutions are some of the most important organisations in South Africa, as they enable the nation by producing knowledgeable and skilled individuals to service the country (Harman & Meek, 2002).

1.5.1 Primary goal of the study

The primary objective of this research was to create a framework for measuring sustainable green IT in the educational system of South African universities that would also be applicable to other areas such as schools, colleges and higher education institutions. It also aims to primarily determine the attitude of academic professionals and encourage them to implement green IT in their daily life through underlining green IT implementation benefits in terms of economic, social, environmental and technical well-being. Over and above that, scientific research and innovation help to understand the several facets of climate change and will be fundamental in developing philosophical thoughts and technologies to mitigate and adapt to climate change.

1.5.2 Secondary goal of the study

Having given special consideration to the primary objective, we realise that the objectives of the study led to the following secondary goals:

1. To implement practices of electronic waste management reducing, reusing and recycling electronic waste, so as to benefit education, the local community and the country at large and to reduce the pressure on non-renewable resources.

2. To enable eco-sustainability in reducing the carbon footprint and energy consumption, in order to assist South African universities to conceptualise and measure their green IT readiness.

3. To improve the acquisition, utilization and effectiveness of technology in universities and critically evaluate dynamic learning experience which develop a green IT model that in order to establishes a holistic approach to the use of green IT products, applications, services and practices.

4. To determine green business practices entail and examine the impact of the start-up cost in implementing rapid technology change that offers considerable under-powered (energy-saving) benefits for adopting green IT products, applications, services, policies and practices.

The researcher believes that there is a crucial need for understanding the responsibilities towards the adoption of green IT for environmental sustainability in South Africa. Sustainable green IT is a critical and very current discussion and the subject will continue to be an important issue for several years to come. Yet there are a number of misapprehensions about what it really means (Gingichashvili, 2007). Some of the subjects are complex, while others are pretty straight and accelerative. Briefly, sustainable green IT is a very important issue, but it is also a very complicated one, for it has many challenging subjects. However, the researcher would not have done this effort if it were not thought-provoking and demanding.

1.6 Significance of the study

Green IT is still in its early stages and is without doubt firmly concreted to drive improved organisations, to encompass corporate growth, more dynamic business strategies and, very important, the environmental footprint of companies and organisations today. The field is

new and evolving; there are few guidelines and best practices available and enabling the effects of these is not yet so widely discussed (Gibson, 2008).

The South African government has been faced with the challenges of ensuring continuity, consistency and an improvement of generating electricity since 2007 (Eberhard, 2012). This study, sheds more light on possible solutions to manage the demand of transforming the appearance of blackouts in terms of power efficiency. As a result of this, the researcher believes, the study makes a contribution to diagnose and remedy the challenges related to implementing energy-efficient resources and environmentally sound components, refurbish and re-use old computers and properly recycle obsolete computers, offer green and cost-control imperative products, operation, application, service and practices to address climate change and the economy of the country.

We all, as citizens of this terrestrial planet, should care and get concerned with one another so that every person, community, and nation on Earth can ensure their sustainable survival. Environmental sustainability is unsympathetically important to all people including future generations because the environment provides the three most significant things on which human beings depend for existence: air, water and food.

The researcher accepts the fact that this study of green IT has the potential to improve the environmental sustainability, in making a real difference in higher education institutions by reducing greenhouse gas emissions, reducing the energy consumption of the IT process and improving the utilisation of natural resources. Furthermore, it may also contribute to the safety of the environment by means of recyclable waste disposal and the construction green buildings and a increased commitment to green transport, which will benefit the society at large. However, all these will only be achieved if IT is managed and done in a responsible and appropriate way. Additionally, the study will contribute to reflecting on the role of environmentally sound technologies for sustainable development and becoming aware of green IT and making simple changes in activities of the inhabitants of the earth, which will change the world dramatically in minimizing the human impact on the environment.

Students, academic staff members and employees need to understand the essential environmental education and take actions that will help protect the academic institutions by becoming aware of the environmental problems. Universities as educational entities should teach and organise conferences for staff and students about global warming, climate

change, renewable resources and all the exciting technologies utilizing these, and even more about the recycling of solid waste, access to clean water, clean energy as well as green buildings and green IT designs.

Apart from the fact that technology causes some environmental issues, it is also one of the paramount tools to help the human race understand climate change modelling that requires massive computer processing capabilities that more accurately represents the conditions of the atmosphere. Once again, besides causing some environmental issues, technology also helps to identify suitable storage areas in carbon capture and sequestration (CCS). Carbon capture and sequestration technology benefits the Earth by reducing carbon pollution and moves us toward a cleaner, more stable environment (EPA, 2013c).

Reflecting on all the afore-mentioned significances of the study, we realise their support in providing universities with a starting point and setting a framework for moving forward to green and sustainable IT organisations. It is impossible to properly evaluate the effectiveness of green IT without knowing how much power IT is consuming and what problems it is causing. However, IT has made it far easier to limit or prevent the damage of the environmental impact by using alternative developments and the production of devices that promote energy conservation. Therefore, the findings of this study unveils gaps based on the importance of the adoption of green IT, explores innovative approaches and practices to advance green education within South African universities' perspectives.

1.7 Unique contribution to the body of knowledge

Information Technology is an essential part of all South African higher education institutions (HEIs). It affects major administrative and academic functions and business processes (Jansen 2010). As a result, the HEIs had to re-examine and reposition themselves in an environmentally-friendly manner. Even though, there has been some studies concerning green IT in South Africa from various authors such as Howard (2014) on banking systems; Petzer, McGibbon and Brown (2011) on the adoption of green IS and Thomson and Van Belle (2014) on drivers of green information technology in higher education institutions, this research goes further and adds to these studies by attempting to create a framework for measuring sustainable green IT practices among institutions of higher education in general, and particularly at South African universities.

The study is expected to improve environmental sustainability in developing clean energy and innovative technology towards measuring and creating green IT practices in

computing systems and having a positive effect on both environmental and fiscal concerns. It also presents a set of propositions, perspectives, psychological novelty, and institutional role-modelling to guide future green IT and also provides a blueprint for imminent leaders and green IT policy makers who seek effective change in universities of South Africa.

The expected contributions of this paper are: 1) increasing the efficiency of IT infrastructure; 2) reducing greenhouse gas emissions used in computing systems and IT-related activities; 3) conserving resources used in the universities; 4) encouraging server virtualisation and telecommuting that reduce travel and travel-related emissions; 5) supplying measures to save energy and to be more conscious of energy conservation; 6) contributing to local economic growth and innovative education, and finally, 7) developing ground-breaking solutions for pressing environmental problems. The study makes a significant and original contribution to the academic body of knowledge and furthers environmental sustainability within educational institutions.

1.8 Research methodology

The term "research" is composed of two syllables, "re" and "search". "Re" as prefix means again, anew or over again, while "search" is a verb meaning to examine closely and carefully, to test and try, or to probe (OxfordDictionaries.com., n.d.). Together they form a noun describing, a careful, systematic investigation in some field of knowledge undertaken to establish facts or principles. Research methodology is a logical and systematic search for new and worthwhile information on particular fields of areas. It is an investigation to discover solutions to scientific and social problems through objective and systematic analysis (Rajasekar, *et al.,* 2013).

There is a difference between research methods and research methodology. Research methods, as stated by Kinash (2007), are the methods by which someone uses the technique or process to conduct research into a subject or a topic demanding exploration of experiments, tests, survey and the like. It aims at finding solution to research problems. Research methodology, on the other hand clarifies the methods by which someone proceeded into existing or new knowledge and how systematic research is carried out (Rajasekar *et al*., 2013). It involves the learning of the various techniques and disciplines that can be used in the conduct of research and in the conduct of test, experiments, surveys and critical studies.

This study uses the term "research method" to denote a high-level plan of the research methodology. In contrast, this study uses the term "research methodology" to represent the comprehensive details about how the study accomplishes its research objective (1.5) and answers the problem statement (1.4). The problem statement specified in section (1.4) particularly consists of a complex, unstructured problem that requires the use of intuition, reasoning and memory. The problem statement is complex because, it contains a wide knowledge that can be broken down into a series of well-defined steps about environmental issues, e-waste disposal, energy efficiency, and socio-economic relevance (Glaser & Strauss, 1967). The study uses the grounded theory rather than grounded theory method (GTM) of content analysis by involving exploration and analysis of qualitative data collected by universities in South Africa and results for measuring sustainable green IT practices.

The intention of this research is to create a framework for measuring sustainable green IT practices in universities in South Africa. This sensitivities are subject to people's interpretation or systematic literature analysis and henceforth the organisation of this research can be referred to as being "socially constructed". For this, reason this research turns out to be interpretive in nature following the qualitative survey which allows the involvement of case studies as research method and design.

Based on the grounded theory, interviews were conducted among participants to guide the primary data collection. Each respondent received the same set of questions phrased in exactly the same way to yield data more comparable. In other words, semi-structured interviews were used to avoid questions being poorly organized, vaguely worded, and excessively lengthy. This research entails an empirical investigation using the qualitative survey for reporting the results.

The study measures sustainable green IT practices in universities of South Africa concerning: 1) e-waste and u-waste disposal: to manage some regulations that would improve compliance and ensure better management of e-waste disposal. 2) energy or power conservation: to increase energy efficiency and reducing operational footprints that generate significant energy, power and resources (i.e. equipment, paper, cartridge, toner etc.); in launching paperless statements such as e-payment, e-statement, e-procurement, e-education. 3) implementing sustainable green IT-optimised resources – in choosing green IT-related products and service that reduce the environmental impact (i.e. server visualization and consolidation, storage consolidation and desktop visualization) and

business activity (remote conferencing, telecommuting, printer consolidation, PC power management) and, finally 5) purchasing an eco-friendly range of products and service, focusing on profitability, reliability and effectiveness by using environment-friendly operating processes.

1.9 Theoretical or philosophical underpinning of the study

Creswell (2003) states that the initial point of discussion in any research project should be an unequivocal exposition of a knowledge claim position. The major characteristics of a researcher is to comprehend the subjective word of human experience. Along these lines a researcher usually begins a project with certain proposition about how the knowledge will be attained and in what way understanding will be achieved during the enquiry process. To respond to this situation, the solicitation of theory is enlisted. Theory plays a crucial role in constructing perceptions in providing information on how the reality comes together and how it may be transformed to be more effective.

According to Mertens (1998), the objective of social science is to develop models such as norms, expectations, positions and roles so as to formulate a "generalising science of behaviour", which is the purpose of this study. The intention is also to interpret actions and behaviours and ultimately generalise them into a theoretical explanation of behaviour. Therefore, the problem of enquiry, the question to be answered and research methodology to be applied, as well as the data to be acquired, were all tethered to a theoretical framework that formed the foundation of this study.

Several research paradigms are found in research methodologies, for instance, behaviourism, positivism, pragmatism and constructivism or interpretivism. Every single one of these philosophical paradigm has its own viewpoints from which behaviour can be explained, which then forms the foundation of a study (Lincoln & Guba, 2000). Given the exposition shown in this paragraph, the philosophy underpinning this research is an interpretive paradigm.

Interpretivism is an inductive analysis of identifying repetitive patterns or common themes that amended across the data. It assumes that people create and associate their own subjective and intersubjective meanings as they interact with the world around them (Merriam, 2002). To contribute to sustainable green IT practice, the researcher used all approaches in an inductive and exploratory way (qualitatively), to understand phenomena in retrieving the meanings participants assign to them. Thus, there is no objective reality

that can be discovered by researchers and replicated by others, in contrast to the assumptions of positivist paradigms.

1.10 Layout of the thesis

This research thesis encompasses six chapters in progressive order with the different levels of investigation as shown below in Figure 1.1.

Chapter 1:
General overview of the nature and scope of study

Chapter 6:
Findings, conclusion & recommendations

Chapter 2:
Literature survey

Chapter 5:
Data analysis & interpretation

Chapter 3:
Research design & methodology

Chapter 4:
Presentation of the grounded theory data
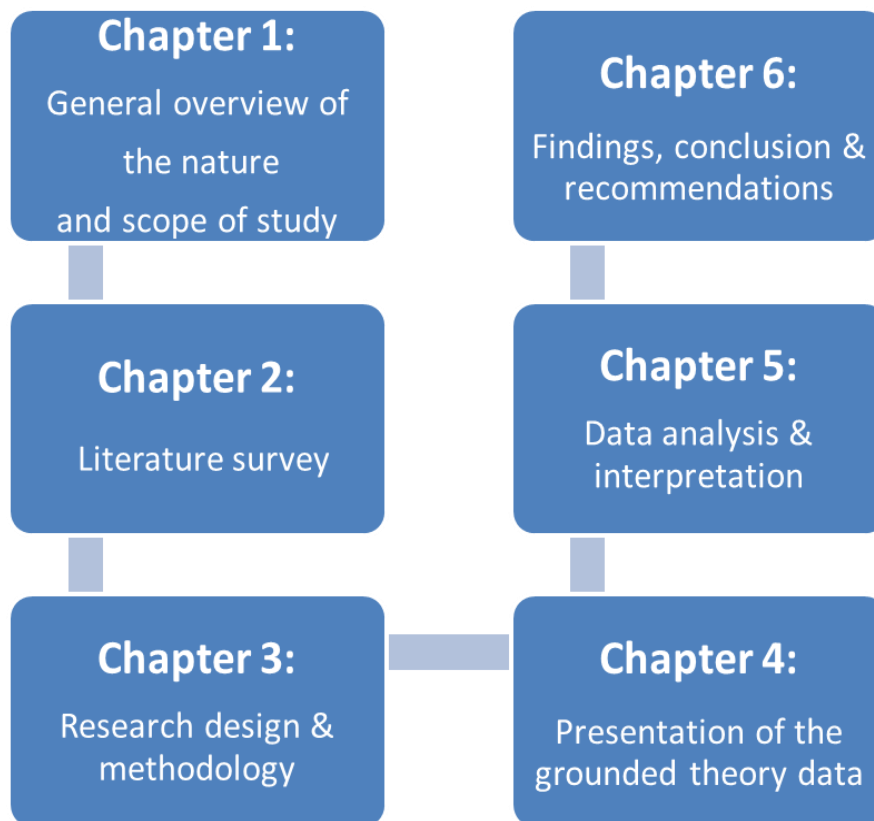
Figure 1-1: Structure map of the thesis

CHAPTER 1**:** General overview of the nature and scope of study: This introductory chapter provides a brief background on how to measure sustainable green information technology practices in universities of South Africa; including motivation for the study, problem statement, research objectives, significance of the study, obstacles to the study, unique contribution to the body of knowledge and the systematic structure of the thesis are also discussed.

CHAPTER 2: Literature review: Following the introductory chapter is the literature review with emphasis on green IT practices and the need to focus on the strength and weaknesses

and pros and cons of the study areas in general. It argues on the past literature reviews done by several scholars that are related and relevant to this field. It also includes a discussion of some of the philosophical, logical, ontological and epistemological aspect of the research that help to develop a theoretical foundations and to guide the research in gathering the appropriate research methodology.

CHAPTER 3: Research design and methodology: The whole research process of acquiring data is described and discussed to justify the choice of the methodology used. It outlines the overall research methodology and design as well as the types of data collection and analysis used to gather primary data. Furthermore, the sampling design, research instruments, their relevance for being used in this research, what the literature postulates about their use as data collection techniques are discussed. It further explores the evaluation of a qualitative interpretive research study and the method used to validate the data is discussed.

CHAPTER 4**:** Presentation of the grounded theory data: This chapter focuses on the theoretical review of the conceptual foundations of sustainable green IT practices. It also explores the implemented grounded theory process as a competent for the framework development and justification in Chapter 5.

CHAPTER 5: Data analysis and interpretation: This chapter exposes the processing, analysing and interpretation of data from which the results are portraying the empirical information on the personnel views with regard the e-waste management, power efficiency, reduction of carbon footprint, hardware and software efficiency, and cost benefit analysis.

CHAPTER 6**:** Findings, conclusion and recommendations: This chapter presents a summary of the most important finding of this study. A discussion on logical conclusion reached and suggestions for the future research follows. Furthermore, recommendations are formulated to sustain, coordinate and capacitate academic users through a proposed sustainable green IT practices model, which is attached in the form of an appendix to this study.

1.11 Chapter summary

This research has the potential impact of making a valuable contribution to universities in South Africa, because it relates to the survival of the present and upcoming generations. It

is only through green IT that an effective choice of organisational decisions can be made in creating "green" economies and more sustainable and equitable societies. IT is the fundamental measure to apply valid technology in self-sustaining communities and green IT is the essential enabler for environmental sustainability.

Education for sustainable development has been identified as an essential priority and motivation for the study. Education is not widely regarded as a problem, although the lack of it is. The fact is that without significant precautions, education can equip people merely to be more effective vandals of the Earth. Education empowers an alteration towards more sustainable behaviours and encourages effective mitigation and adaptation strategies for environmental impacts and supports academics in understanding the value of preserving cultural and other perspectives needed to address current and future socio-economic challenges within the global constraints of climate change and environmental sustainability problems.

The next chapter of the study focuses on literature study, and particularly addresses a research gap leading to a more rapid generation of subsequent research, investigation of new knowledge, and the provision of a framework for measuring sustainable green IT practices in the universities in South Africa.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

This literature review describes divergent themes, theoretical foundations and methodological approaches taken to ensure sustainable green IT practices within South African universities. Based on the previous chapter (section 1.4: Problem definition), the literature review provides a current overview of the existing body of literature, identifying the most dynamic scholars, surveys and relevant publications of journals and books. The literature debates about factors that necessitate green IT practices in relation to designing, manufacturing, using and disposing of computers, as well as utilising server virtualization and IT-associated equipment. It also outlines some of the SWOT (strengths, weaknesses, opportunities and threats) analysis and benefits of the green IT, and proposals on improving energy efficiency, lowering greenhouse gas emissions, using less harmful materials, enhancing resource management and using IT tools to improve environmental education and its responsibility to expand the environmental performance, tackling that causes global warming acceleration (such as desertification, sea level rise and strong hurricanes as well as cyclones).

The major objective of the literature review is to develop a theoretical framework for measuring sustainable green IT practices in universities of South Africa with the objective of answering the research questions and identifying weaknesses or gaps in the study (Webster & Watson, 2002). The literature review ensures that this scientific study supports the claim of a rigorous review and highlights the problems of the research by contributing an original and significant influence to the body of knowledge. It addresses the subjects in relation to the issue of eco-sustainability, energy efficiency, and green IT that cultivate product stewardship focusing on the IT lifecycle from procurement to end of life.

Finally, the literature review highlights the model of green Information Technology practices to which a university can possibly contribute to environmental stewardship and protect the environment while creating fully recyclable products, thereby reducing environmental pollution and proposing alternative technologies in various fields in order to

mitigate the negative impact of computing technology on environment and natural resources.

2.2 Systematic literature search strategy

A systematic review is an examination of an evidently formulated question that uses logical and clear methods to categorize, select, and critically evaluate relevant research, and accumulate and analyse data and information from the studies that are included in the review (Khazeni *et al.,* 2009). Hart states (1998) that there is no single accurate method of writing a literature review. The method for writing literature review can differ from one researcher to another.

A literature review is an examination of the research that has been conducted in a particular field of study and the selection of available information to identify relevant information and to outline existing knowledge in relation to any research question (Hart, 1998; Kitchenham & Charters, 2007). Finding and examining all published studies significant to the key questions is the goal of all systematic reviews. When considering to undertake a systematic review, it should first be determined that a good quality review of the topic of interest does not already exist (Webster & Watson, 2002; Levy & Ellis, 2006).

For this systematic literature review to be comprehensive, critical and contextualised, the researcher used several reputable and credible articles from North-West University Learning and Collaboration Online Environment such as: A to Z journal lists, JSTOR, SAePublications, EbscoHost, LexisNexis, Scopus, Emerald, Juta, ScienceDirect, GoogleScholar, Sabinet Reference (South African Bibliographic and Information Network) and Web of Science to retrieve scholarly journal and books. Besides the afore-mentioned North-West University online journals, the researcher also used some other alternative online electronic journals and books from Elsevier, EBSCO, South African Journal of Science and Science Direct searches to identify South African publications, books, journals, newspapers, web pages, articles and dissertations.

A systematic literature review exposes the key theories, variables, relationships and phenomena that relate to the research problem and discloses the influential researchers in the field (Randolph, 2009). A systematic literature search method initiates the development of keywords. Keywords are the words and terms that constitute the foundation for subsequent electronic literature searches (Klopper & Lubbe, 2011). For an advanced search engine, the Boolean operators (and, or, not) in the google scholar was used to

broaden or narrow the relevant keywords, terminologies and phrases of this subject of this research, such as green IT, green computing, ICT sustainability, environmental sustainability, e-waste and u-waste disposal, energy efficiency and reduction of greenhouse gas emission.

A search can potentially return many literature items. To retain only relevant literature items for use in the subsequent phases of the systematic literature review, the researcher assesses and credits each discovered literature item. The assessment involves scrutinising each the title, of each literature item, its keywords, abstract or summary, introduction and conclusion sections for relevance to the problem statement or definition (Klopper & Lubbe, 2011; Vom Brocke *et al.,* 2009; Brereton *et al.,* 2007).

2.3 Global warming and climate change as ecological (environmental) issues

Environmental problems have become a great concern to society in recent eras. In the past, human being lived in peace with the environment; however, in more modern times human beings started putting pressure on and having rapidly impact on the environment. These changes caused by human activities gave rise to environmental degradation, deforestation, destruction, exhaustion, and causes the globe to head towards total downfall (Benitez-Amado & Walczuch, 2011). Hence, the issue of protecting the environment has turned out to be the main focus of various organisations focused on addressing the growing environmental and social problems in order to be more environmentally responsible (Murugesan, 2013).

Currently, the issue of global warming and climate change have attracted a lot of attention in the mass media. Global warming and climate change constitute the major environmental and humanitarian crises of our time (Natural Resources Defence Council (NRDC, 2012). Global warming refers the increase in temperature of the Earth's surface and its atmosphere (EPA, 2013a). It now affects many areas around the world by accelerating the melting of ice sheets, permafrost and glaciers which is causing average sea levels to increase (National Research Council, 2008). Contrary to global warming, climate change refers to a long-term seasonal change in weather conditions identified by several variations in atmosphere, temperature, rainfall, winds, land and oceans along with snow and other indicators (EPA, 2012a).

Due to the release of greenhouse gases, the earth's average temperature has increased by 1.4°F over the past century, and is expected to escalate again with between 2 and 11.5°F over the next hundred years (EPA, 2013a). Minor changes in the temperature of the planet can translate to high average temperatures and potentially dangerous shifts in climate and weather.

Theoretically speaking, there is a discreet difference between weather and climate as well. According to Hassol (2002), weather refers to the conditions that happens at one particular time and place, and can vary within a certain time, day and season, while, climate, on the other hand, refers to the long-lasting average pattern of weather in a place. Basically, long-term data are required to determine variations in climate, and such data indicate that the earth's climate has been warming at a swift rate since the intensive use of coal and oil in the late 1800s.

The Chevron Company (2012) states that as the temperature continues to increase due to climate change, global warming will undeniably have the largest impact on natural and human systems all around the world; the largest impact will be on many natural ecosystems. An engineer and science writer, Auerbach, highlights the danger of global warming and climate change is as certainly the greatest environmental threat that humanity has to face in the coming 100 years (Mail Online, 2010).

Global warming and climate change are caused mainly by carbon dioxide from burning fossil fuels such as coal, oil and gas (EPA, 2013a). This causes a build-up of carbon dioxide, methane, nitrous oxide and water vapour gases in the atmosphere of the earth that absorb heat. Natural gas which is made up of compounds of hydrogen and carbon is approximately half as CO_2-intensive as coal per unit of electricity generated. WWF Global (2012) specifies that some environments (e.g. the Arctic tundra) get warmer and also release CO_2 that may have been stored for centuries. Greenhouse gases (GHG) being a major cause to climate change are released into the atmosphere in several ways. One of the ways due to technology creates large amounts of waste and air pollution. EPA (2001) projects that currently the surface of the atmosphere contains about 660 billion more metric tons of carbon dioxide (CO_2) than it did in the past.

New technology can enable the efficient production and transportation of natural gas supplies for power generation, as well as the development of ultraclean diesel fuel from natural gas (Chevron Company, 2011). Socolow and Pacala (2006) noted that the use of

alternative technologies such as wind, solar and nuclear energy could solve a significant portion of the environmental problems, by preventing global emissions of greenhouse gasses from rising for the next five decades. Madeira and Erin (2008) state that changes in forestry and farming techniques also lead to a substantial reduction in carbon emissions. Socolow and Pacala (2006) once again emphasise that scientists must continue researching alternative sources of energy needed 50 years from now because by that time some of the technologies used today will have reached their full consumption and may not be able to keep up with the increased demand.

Knutson (2008) warns that carbon pollution and the resulting climate change are expected to lead to more intense hurricanes and storms, heavier and more frequent flooding, increased drought, and more severe wildfires. Society will experience catastrophic effects resulting from climate change, such as an accelerating rise in sea level, droughts, floods, storms and heat waves (EPA, 2013a). These will impact some of the worlds poorest and most vulnerable people, disrupt food production, and threaten vitally important species, habitats and ecosystems. FAO (2008) clearly indicates that Africa is the most vulnerable to climate change as the continent is constantly pursuit of water and food security as well as sustainable development.

Some scientists (Oreskes, 2004; Hunsen, 2008; Anderegg *et al.,* 2010) agree that global warming is a serious problem of our time and is steadily growing worse. On the other hand, other scientists agree that global warming is not worth worrying about (Coleman, 2014). Others still disagree over man's contribution to the change by affirming that some think it is natural and others think the main cause is as a result of human manipulation of the eco-system due to burning fossil fuels that are largely responsible for driving the change (Ekins *et al.,* 2003). This driving force is, to some extent, what scientists now refer to as climate change or global warming.

EPA (2011) relates global warming to the increase in the earth's average surface temperature due to a build-up of greenhouse gases in the atmosphere whereas climate refers to long-term change in climate, including average temperature and precipitation. It does not matter whether it is due to climate change or global warming, more and more scientific research and worldwide studies declare with a growing certainty, that this increase in the earth's surface is due to the greenhouse gases produced by humans (National Research Council, 2011).

2.4 Natural and human-related environmental problems

There are generally two causes of global warming and climate change. These are natural causes and anthropogenic (human) causes. The Geological Society of America (GSA, 2006) agrees with the assessments of the National Academies of Science (2005), the National Research Council (2011), and the Intergovernmental Panel on Climate Change (IPCC, 2007a) that global warming and climate change are here and that human activities (mainly greenhouse gas emissions) account for most of the warming since the middle 1900s. To the contrary, there are scientists who do not agree that humans rather than natural force are the cause of the change (Bellamy, 2013; Dyson, 2014).

Broad scientific, economic and political consensus has been established that climate change poses a threat to the whole world (Melville, 2010; Watson *et al.,* 2010; Molla, 2009). Environmental problems are affected by both natural and human causes. However, human activities are primarily responsible for ecological issues. Many scientists agree that humans are by far the dominant cause of recent global warming (Weart, 2011; Anderegg *et al*., 2010; Oreskes, 2004). Among the many influences, the two largest human influences are greenhouse gas (GHG) and sulphur dioxide (SO_2) emissions, mostly from burning coal, oil and natural gas (sulphur emissions tend to have a net cooling effect). Lott (2012), an attribution scientist in the UK Met Office and EPA (2013a), pointed out that the only way to explain the changing climate was through a combination of natural and anthropogenic (man-made) factors.

2.4.1 Natural causes

There are a number of natural factors responsible for climate change. Some of the more prominent ones are (1) continental drift which affects the physical landscapes of the landmass, volcanic eruptions that throw huge volumes of sulphur dioxide; (2) water vapour dust and ash into the upper levels of the atmosphere (known as stratosphere); (3) ocean sediments; (4) the earth's tilt; (5) solar and orbital variations; and (6) the chemical composition of the atmosphere (Carnagie *et al.,* 2008). According to the WWF Global (2012), global warming will have catastrophic effects such as accelerating the rise of the sea level, floods, droughts, storms and heat waves. These will impact on some of the world's poorest and vulnerable people, disrupting food production and threatening vitally important species, habitats and ecosystems, if scientists and economists are negligent to safeguard a sustainable future for people, places and species.

Water-related sources such as oceans, seas, rivers and lakes supply drinking water for people and animals, as well as being vital for agriculture and industry. Global warming and climate change have a significant and unpredictable effect on the world's water systems, resulting in more floods and droughts (FAO, 2008). Extremes of drought and flooding will become more common, causing displacement and conflict while less fresh water means less agriculture, food and income (WWF Global, 2012). As opposed to the current situation in general, as stated by the Environmental Protection Agency (EPA, 2013a), climate changes prior to the Industrial Revolution (1700) can be explained mainly by natural causes rather than anthropogenic forces.

2.4.2 Human (anthropogenic) causes

As mentioned earlier in section 2.4.1, climate changes cannot be explained by natural causes alone. The National Research Council (2011) and EPA (2013a) indicate that natural causes are very unlikely to explain most of the observed warming, especially warming since the mid-20th century. Human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. The National Aeronautics and Space Administration (NASA, 2013) identifies multivariate anxieties over uncertainties as potential causal forces influencing climate change and global warming; including the impact of solar irradiance, aerosols, dust, smoke, clouds, the carbon cycle, ocean circulation, precipitation and sea level rise.

The impact of the natural causes to the environment due to variations in the reflectivity of the Earth's atmosphere and surface is true. Nevertheless, climate change and global warming cannot be explained by natural cause alone. There are also some human causes which are responsible for the environmental issues. Hence, it is important to discuss some of the human causes leading to the impact on the earthly planet.

2.4.2.1 Air-related anthropogenic environmental problems

The addiction of society to fossil fuels is bringing about confusion in the perfect balance of nature and threatening the survival of the entire generation. Burning fossil fuels increases the amount of carbon in the atmosphere, leading to an increase in the greenhouse gas effect. The greenhouse problem begins when human activities distort and accelerate the natural process by creating more greenhouse gases in the atmosphere than are necessary to warm the planet to an ideal temperature (Socolow & Pacala, 2006).

Climate change is one of the major challenges facing the world due to increased carbon emissions that contribute to global warming. It is believed that over the last century, the amount of gases in the atmosphere from carbon emissions, mostly carbon dioxide and carbon monoxide, are greenhouse gases that are produced by anthropogenic factors. Greenhouse gasses are gases in the atmosphere that trap and reflect heat and radiation back to the earth's surface. Anthropogenic factors have contributed substantially to climate change by adding CO_2, primarily by the burning of fossil fuels and other heat-trapping gases to the atmosphere. These greenhouse emissions have increased the greenhouse gas effect and caused the Earth's temperature to warm up (EPA, 2013a).

An emission from the burning of natural gas, coal and oil including petroleum for automobile engines raises the level of carbon dioxide (CO_2) in the atmosphere. Contaminated natural gas produces more indoor air pollution than tobacco or secondary smoke. It can be surmised that gas combustion is the largest and most dangerous source of pollution that people are exposed to. Burning natural gas in the place of other fossil fuels emits fewer harmful pollutants, and an increased reliance on natural gas can potentially reduce the emission of many of these most harmful pollutants (LaMonica, 2011). Many factories produce long-lasting industrial gases that do not occur naturally, yet contribute significantly to the enhanced greenhouse effect and glob warming that is currently under way (IPCC, 2007b).

Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (Hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) that trap heat and lead to higher gas concentrations in the atmosphere are rising more rapidly than predicted and the world is warming more quickly in response. These factors have caused the earth's climate to change many times (EPA, 2013a). Throughout earth's history, changes in carbon dioxide levels have been linked to changes in climate. Current global emissions of carbon dioxide contain 7 billion tons of carbon per year. Moreover, that amount is projected to double to 14 billion tons per year over the coming 50 years as the world population increases and people consume more energy (Socolow & Pacala, 2006).

Karin (2008) indicates that the stratospheric ozone (the second major layer of Earth's atmosphere) is being destroyed by a group of manufactured chemicals, releasing chlorine or bromine that adds to the ozone destruction. These chemicals are called "ozone-depleting substances". The chemical compound ozone plays a substantial role in absorbing harmful ultraviolet radiation from the solar system. During the past 20 years, concentrations of this

important compound have been threatened by human-made gases released into the atmosphere, including those known as CFCs (Chlorofluorocarbon – a chemical compound). These chemical compounds as well as meteorological conditions in the stratosphere affect the concentration of the stratospheric ozone.

The EPA (2013d) highlights to the United Stated Congress that the current energy consumption in data centres is consequently resulting in the annual increase of the greenhouse gas emissions. Uddin and Rahman (2012) concur that the IT industry is accountable for 2% of global emissions, which is approximately equivalent to emissions from the aviation industry. Therefore, if the IT equipment's power consumptions and greenhouse emissions continue growing at the current rate, emissions are expected to double by the year 2020 (Ponnavaiko, 2013). Due to the huge amount of carbon emissions, the ozone layer is getting thinner, which is dangerous for the human body. There is a continuous requirement for a flexible, dynamic and secure green IT framework to deal with energy issues and reduce the carbon footprint in data centres and computation processes (Karin, 2008).

2.4.2.2 Water-related anthropogenic environmental problems

Water plays a crucial role in nature for the survival of any living thing. Lack of quantity and quality of water can threaten the existence of living elements in the marine and terrestrial ecosystems. The oceans supply plenty of living organisms and marine wildlife with basic nourishment and is a sensitive ecosystem that can be polluted very easily. For instance, oil spills, by Exxon Juan-Valdez in 1989, left the Alyeska Pipeline and crossed Prince William Sound carrying approximately 53 million gallons of crude oil and upset the society for decades or even centuries (McClure, 2004).

There are a number of other water-related environmental problems that affect climate change such as acid rain, waste water, urban run-off, eutrophication, water crises, marine pollution and acidification (EPA 2013b). Even though, water pollution is usually caused by human activities, such as dumping waste into the oceans through different means: pipelines, sewers, underground mines, oil wells, oil tankers, sludge, and garbage, the researcher would like to focus especially on to what extent the technological revolution is going to have an impact to the environment.

Normally, rainwater has a pH (potentiometric hydrogen) of about 5 to 6. This means that it is naturally a neutral and slightly acidic liquid. During precipitation rainwater dissolves

gases such as carbon dioxide and oxygen. Industry and technology emit great amounts of acidifying gases, such as sulphuric oxides and carbon monoxide. Rain with a lower pH, due to dissolved industrial emissions, is called acid rain. This causes a change in pH of the precipitation (EPA, 2012b).

Acid rain is all forms of acid precipitation such as rain, hail, snow, sleet, or fog containing high levels of sulphuric or nitric acids with a pH scale below 5.5-5.6. Acid rain is produced when sulphur dioxide and various nitrogen oxides combine with atmospheric moisture (EPA, 2012b). As a result, the compounds can travel long distances where they become part of the rain, sleet, snow, and fog that can be experienced on certain days. The subsequent acid rain can contaminate drinking water; erode buildings and damage vegetation and aquatic life (EPA, 2013b). Automobile exhaust fumes and the burning of high-sulphur industrial fuels are thought to be the main causes, but natural sources, such as volcanic gases and forest fires, may also be major causes.

The manufacturing technology creates large amounts of waste, and obsolete computers and electronics get thrown out when they break or become outdated. Incorrectly deployed waste computers and electronics usually end up in a landfill. Electronics contain non-biodegradable materials, heavy metals and toxic materials like cadmium, lead and mercury (Sabha, 2011). Over time, irregularly disposed electronic-toxic materials that are unsafe for the environment leak into the ground and oceans where they can contaminate the water that humans and animals drink and the plants human beings eat and the animals that live around the area depend on (Halfman & O'Neill, 2009). Pollutants (harmful gradients of chemicals) from such areas contaminate water bodies and rivers and even pollute the ground water in many places. Studies have also shown that crops are contaminated through industrial effluents but the scale of such an impact has yet to be identified (Midrar Ul Haq & Memon, 2005).

Computers contain all sorts of chemical components. They contain mercury, arsenic, cadmium and chemical fire retardants. Once this toxic substances gets into the ground water, it can flow out into the environment and cause havoc for decades to come. Lloyd-Smith and Immig (2011) has given a devastating analysis of the poisonous effects of the destructive industry that creates an environmental monster for the future and the dangers of dumping techno trashes.

2.4.2.3 Land-related anthropogenic environmental problems

Land-related environmental problems are problems arising from inefficient land use such as urban sprawl, habitat fragmentation and habitat destruction. Other anthropogenic activities and their consequences continue to pose threats to land-related environmental problems and arising from land pollution, soil pollution, degradation and desertification. Urbanization and climate change are the two most important elements to shape the global development. Cities have the potential to serve society in providing education, health care, reliable access to technology, sanitation and electricity. On the other hand, cities put more pressure on natural resources depletion than rural communities; allowing the residents to live densely and the attendant demands on excessively water, agricultural, energy, and other resources. Climate change could undercut all of this by exacerbating resource scarcity and putting vulnerable communities at risk (Pillai, 2012).

Afforestation, reforestation and forest management (forestation) play a great role in reducing deforestation, purifying air, improving water quality, keeping soils intact, providing food and medicines for human being and animals as well as home to many of the world's most endangered wildlife (Madeira & Erin, 2008). The Food and Agriculture Organisation of the United Nations (FAO, 2008) estimated that 1.6 billion people worldwide rely on forests for their livelihoods, including 60 million indigenous people who depend on forests for their subsistence. Forests also help protect the planet from climate change by absorbing massive amounts of carbon dioxide (CO_2), a major source of pollution that causes climate change.

Unfortunately, forests are unceasingly destroyed or damaged at a terrible rate through logging and burning to clear land for agriculture or livestock. These activities release huge amounts of carbon dioxide and other harmful greenhouse gases into the atmosphere. Madeira and Erin (2008) estimate that up to 20% of global carbon emissions come from deforestation, which is far more than emissions from every car, truck and plane on the planet combined. So, instead of forests helping society to solve the climate crisis, deforestation is making the situation even worse (WWF Global, 2012).

FAO (2008) demonstrates deforestation as the major problem to global warming. Trees use carbon dioxide and give off oxygen in its place, which helps to create the optimal balance of gases in the atmosphere. As more forests are logged for timber or cut down to make way for farming, there are fewer trees left to perform this critical function. Population

growth (overpopulation) is also another factor in global warming, because, as more people use fossil fuels for heat, transportation and manufacturing, the level of greenhouse gases continues to increase. As more farming occurs to feed millions of new people, more greenhouse gases enter the atmosphere (Harte, 2007).

Technology itself is not bad at all; the negative impact thereof lies within the people who use or misuse it. It has brought positive results because of its unceasing improvement of social well-being. For instance, technology has created an operation alert and mapping system that provides close real-time information related to the detection of a previously unmapped type of wildfire against deforestation and other burning-related environmental problems. The Wide Area Monitoring Information System (WAMIS, 2012) explains how the process works in South Africa, using an innovative satellite imagery derived from the Terra and Aqua MODIS and Meteosat Second Generations (MSG) to serve continuous data streams captured and processed by South Africa National Space Agency. A daily forecast of fire danger and real-time visualization of severe weather can be done remotely using either radio frequency (RF) or cellular/satellite networks. A remote-start system allows owners and agencies to protect private households and assets from a distance without compromising safety. These data improve the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

2.4.2.4 Technology-related anthropogenic environmental problems

Technology integration in the business environment is a necessity in order to remain competitive in modern markets, despite the fact that electricity is a major cause of climate change, because the coal or oil that helps generate electricity also releases CO_2, pollutants, and sulphur into the atmosphere (Murugesan, 2008). These emissions can cause respiratory diseases, smog, acid rain and global climate change. Reducing electric power consumption is a key to reducing carbon dioxide emissions and its impact on our environment and global warming (EPA, 2013c).

With the desire for new and emerging technologies consumers use and replace electronic devices at an astounding rate. According to the United Nations Environmental Programme (UNEP, 2008), 20 to 50 million metric tons of e-waste are generated worldwide every year, with 5.5 tons composed of computers, cell phones and television sets. The rapid increase in e-waste makes it necessary for manufacturers and municipalities to encourage responsible electronic disposal.

EPA (2013b) highlights that 80 to 85% of e-wastes was discarded in landfills or incinerators, which can release certain toxics into the air. Sabha (2011) indicates that households and small businesses discard computers that are outdated in favour of newer technology (model), even if they are still in good working condition. This practice denies the benefits of technology to secondary users such as schools, non-profit organisations, small businesses or students. EPA (2014) encourages consumers to donate old computers in order to conserve natural resource and avoids greenhouse gases emissions and water pollution.

The donation of working computers and their peripherals extends their usefulness and keeps them out of landfills and incineration longer (EPA, 2013b; EPA, 2014). Although it is legal to export e-waste to developing countries if they can be re-used or refurbished, as indicated by the Guardian (2013), the level of e-waste being shipped to Africa or Asia under false pretences (disguised as used goods), causes significant environmental pollution and health risks for local populations.

Although technology is fundamentally changing the way mankind lives, boosts business activities and creates employment opportunities, it is also affecting the health status in more than one way. The widespread use of electronic items has brought into focus many challenges. Everyday gadgets are adding physical distresses in human health, as well as the increasing problems of e-waste. A research conducted, by Kohli (2013) at the University of Gothenburg in Sweden, indicates that the use of cell phones and computers can be linked to an increase in stress, sleep disorders and suffering from increasing Computer Vision Syndromes (CVSs) such as evaporation of tears, blurred vision, double vision, dry, red eyes, eye irritation, headaches and neck or back pain as well as Carpal Tunnel Syndrome (such as a slight cramp, a muscle spasm and carpal tunnel pains).

Forestry, as widely explained in section (2.4.2.3 viz. land-related environmental problem), is the main sustainable industry of all the primary industries that provide individuals with energy and materials to address climate change (Madeira & Erin, 2008). However, when using any form of media for Information Technology, there is always the question of the environmental and social impact. One of those forms of media is paper, because hard copy (print) is carried out on paper of which over 90% comes from virgin tree fibre. Though the main cause of deforestation is either for agriculture, buildings or energy requirements, the paper industry that manifactures paper to be used in technology is relatively small; it should not be taken for granted as well.

2.5 Sustainable green IT and sustainable development

Sustainable development is widely applied in the business area, and most often understood as maximising profitability while minimising environmental resource depletion and degradation. This interpretation encompasses organisations between economic gain, social benefits and environmental impacts, however, always with the precondition of economic gain (Laine, 2010; Diedrich *et al.,* 2011).

According to Rainey (2006), the concept of sustainable development (SD) is an approach for improving the quality of life while conserving the environmental potential for the future, of living off interest rather than consuming natural capital. Beatley and Manning (1998) describe sustainable development as social responsibility, environmental protection and economic progress. The Brundtland report of the World Commission on Environment and Development (WCED, 1987) defines sustainable development as a development that meets the needs of the present without compromising the ability of the future generations to meet their own needs.

The Brundtland report (WCED, 1987) highlights the enduring aspect of the concept of sustainability and brings into light the ethical principle of achieving equity between the present-day and future generations. The context in which the definition is embedded indicates that "necessities" include a sound environment, a just society and a healthy economy, but is not intended to mean sustaining practices, industries and organisations that are harmful to these three requirements. Diesendorf (1999) describes sustainable development as types of economic and social development which protect and enhance the natural environment and social equity.

Sustainable green IT refers to the study and practice of designing, manufacturing, using and disposing of computers, servers, and associated subsystems (Murugesan, 2008). The green IT as one of the sustainable developments addresses environment-related risk mitigation. Vesilind *et al.* (2006) assert that green IT is the means for attaining sustainability, and the purpose of the sustainable green IT is to reduce the carbon footprint of IT systems' performance.

According to Jenkin *et al.* (2011), information technology, systems initiatives and programs that address environmental sustainability is referred to as sustainable green IT. Molla (2009) defines the systematic application of environmental sustainability criteria as the design, production, sourcing, use and disposal of the IT technical infrastructure; also

the human and managerial components of the IT infrastructure are regarded as sustainable green IT (Molla, 2009). To Murugesan (2013), sustainable green IT is at the service of sustainable development on its high-tech component and aims at designing efficient and cost effective products and service of computers and IT-related equipment in building a green society and economy.

Computers, laptops and mobile devices of IT are not only a booming economic sector but also an energy intensive one. In 2005, 4.5% (120 TWh/a) of the electrical power in the European Union (EU-27) was spent by consumer electronics such as TVs and Hi Fis, and 3.5% (97 TWh/a) for ICT mainly PCs, telephones and the communication infrastructure including data centres (European Commission, 2009). The 2020 business-as-usual (BAU, 2012) projection predicts that ICT-related energy consumption will rise to over 400 TWh, mainly driven by the expected diffusion of larger-screen TVs, higher-speed broadband access, and higher-capacity data centres. This figure can be reduced if the green segment, or sustainable green IT, continues to grow (Coroama & Hilty, 2009). ICT has an enabling potential for energy efficiency which can only be realized in conjunction with further conceptual, technological and organisational solutions (Howard, 2014). The three main approaches to the sustainability of a green environment can be accomplished through social responsibility, environmental protection and economic progress (Jenkin *et al.,* 2011).

2.6 Enabling sustainable green IT for eco-efficiency

This literature conveys sustainable green IT for eco-efficiency as an essential role in society and is a critical factor for economic growth and the solution of environmental problems. There are several issues to be raised regarding sustainable green IT in relation to the sustainable environment. Some of these issues are: whether technology is manufactured eco-friendly, or recycled easily or uses efficient electrical equipment. Besides, though new technologies are important for helping old technologies, they are also inevitable for important assessments to be undertaken. It should not be introduced merely because it is new. For instance, the new innovation fluorescent light bulbs versus incandescent light bulbs uses less energy, but on the other hand also uses more toxic chemicals (mercury). Thus, considerations and assessments of innovated devices are compulsory.

Sustainable green IT for eco-efficiency generally deals with aspects of using low emission carbon footprints, alternative energy-efficiency technologies, having recyclable customs, analysing durable life cycle assessments and other alternative uses and practices of green technologies to confront environmental problems. In other words, it is all about adhering to quality product materials, low energy consumption, and cost-efficiency that each and every user can save money and have efficient technologies with longer-lasting products (EPA, 2013b).

2.6.1 Efficient use of natural resources and resource depletion

Undeniably, natural resources support the economy and quality of life. In the past, as Otto, Monchuk and Jintanakul (2007), affirm there was no competition for natural resources for the resources were abundant, and the economy made use of the resources in limited ways. Currently, events have changed. Economic competition for natural resources is real, complex and growing.

Increasing resource efficiency is a key to securing growth and jobs for the sake of the country. It will bring major economic opportunities, improve productivity, drive down costs and boost competitiveness. Companies that efficiently use raw materials, water and other manufacturing inputs for their products are able to cut costs, which helps them to become more competitive (Watson & Boudreau, 2011).

As highlighted by the European Commission (2011), some European countries are already innovating in and reaping the rewards of resource conservation. For instance, in Hungary, 56 companies have introduced environmentally friendly technologies that have saved them €59m. Similarly, in the Netherlands, a chemical company that was consuming 9,9 million litres of fresh water per day switched to household waste water, resulting in the company using 65% less energy and 500 tonnes less chemicals per annum. It has also mitigated the greenhouse gases emissions by 5,000 tonnes.

In Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2011) in respect to sustainable production and consumption patterns and processes aims to widen the knowledge about material use in industrial and developing countries. It also analyses the association to sustainability, analysing the relationship between society and natural resources also called "social metabolism". The research investigated the causes and consequences of resource use and the potential for a transition towards sustainable resource use patterns in Australia and elsewhere. The objective of the research was to

develop knowledge that supports the sustainable use of natural resources, practice, policy, management and transition pathways for sustainable resource use, including adaptive responses to climate change. This efficient use of natural resources can be applied in the same way to other countries of the world including South Africa.

2.6.2 Energy efficiency and energy conservation

Murugesan (2013) states that the biggest challenge about climate change is that there is no one single answer, nor single solution to it. According to him, IT professionals really need to develop a whole host of technologies and continue to improve the energy efficiency that is a global issue, both now and in the future. Many clients in growth markets such as China and India are looking at how to grow their use of IT and do so in an energy-efficient manner often with government support to save energy. Modern IT systems rely upon a complicated mix of people, networks and hardware. As such, a green computing initiative must cover all of these areas in a comprehensive way. A solution may also need to address end-user satisfaction, management restructuring, regulatory compliance and return on investment.

Emerging technology and as yet unknown technological breakthroughs have the potential to significantly reduce GHG emissions if they can be developed to commercial scale. In fact, the International Council on Clean Transportation (ICCT, 2011) confirms that technologies have not achieved the levels of market maturity and penetration as intended. If new technology passes to market to mitigate the excess carbon emissions depending on improved technical analysis and designed performance, it will benefit sustainable development (EPA, 2001; Molla, 2009). Climate change benefits will come from multiple solutions that will be developed over time largely from technology. Having the right technology and making appropriate use of technology can lead to undeniable power saving, not only in computers but also in motor vehicles technology is effective at controlling nitrous oxide emissions, and at reducing all hydrocarbon exhaust emissions including methane.

Energy is a key factor in discussions of economic, social and environmental dimensions of sustainable green IT. Technology has the carrying capacity to enhance energy efficiency across a wide range of activities. Buildings, for example, directly and indirectly generate substantial emissions. New advances in design and construction, such as ventilated double-skin facades, glass coatings and advanced batteries that can store solar power, can

significantly reduce the power demand and lower CO_2 emissions (Chevron Company, 2012).

Technology is advancing across a wide range of renewable energy sources such as biofuels, wind, solar and geothermal. Cellulosic conversion technology, for example, is currently being developed to enable a wide variety of agricultural and forest waste to be manufactured into non-carbon transportation fuels (Chevron Company, 2012). Nuclear power is another option in the energy portfolio as it is carbon emissions-free. Besides from being carbon free, Carvalho (2011) states that significant strides have been made in operational safety, and improvements will need to continue, as well as measures to address waste storage issues.

A study done by Herzog and Golomb (2004) demonstrates that CO_2 resulting from the production and combustion of fossil fuels can be captured and stored with current technologies, but at a great cost. To capture a significant amount of the world's CO_2 emissions, particularly from coal-fired power plants, will require new, large-scale infrastructure. Initiatives are under way to advance this technology. It is critical to further reducing costs and assess the commercial scale of this technology (Carvalho, 2011).

Today, the rising cost of energy is posing serious challenges to the sustainability of the global digital economy, and it is bound to increase even further in future. Uddin and Rahman (2012) state that IT consumption has far-reaching implications for humanity's economic sphere. It is one of the major energy consumption growths worldwide, equivalent to usage in the airline industry. Hence it makes sense, as emission reduction becomes desirable and even mandatory, that IT users must look at ways of reducing the energy consumption of their systems.

To remain eco-friendly, organisations need to move to green Information Technology for cost-effectiveness and reduction in the usage of power and applying the work of researchers to develop new products and processes in technology. Data centre operators have understood that the established practices of running huge numbers of significantly underutilised servers no longer work and are excited for energy-saving solutions, due to the rapid, unabated rise in electrical power consumption and the associated financial and environmental costs (Uddin & Rahman, 2012).

According to the US Environmental Protection Agency (EPA, 2010), if every home in America replaced just one incandescent light bulb with an Energy Star compact

fluorescent light bulb (CFL), in a year, it would save enough energy to light more than 3, 000 000 homes. That would prevent the release of greenhouse gas emissions equal to that of about 800, 000 cars. Even though, the major users of electricity are residential, commercial buildings, industry, transportation, and electric power generators, schools and educational entities represent the largest non-residential building sector. Therefore, replacing the bulbs would have an enormous impact.

The Energy Information Agency (EIA, 2013) reports that offices annually consume 676 trillion BTU (British thermal unit – 1 unit equals 1055 Joules) of electricity and natural gas. Offices are the prevalent users of energy among all of America's building types. According to the EIA report, offices spend $14 billion on electricity and $1 billion on natural gas annually. On average the energy costs of an office building are about $1,50 per square foot compared to approximately $1,10 per square foot for other types of commercial buildings.

2.6.3 Mitigation of carbon footprint pollution

Reducing carbon footprint emissions while maintaining economic growth and improving the quality of life is one of the essential challenges of this millennium, and sustainable ICT offers the opportunity to address the threat of climate change while sustainably growing the world's economies. The study conducted on global greenhouse gas emission by the Boston Consulting Group (2013) states that the increased use of Information and Communication Technology (ICT) such as video conferencing and smart building management could possibly cut global greenhouse gas (GHG) emissions by 16,5% by 2020 resulting in $1,9 trillion in gross energy and fuel savings.

Global carbon emissions attributable to ICT have been estimated at 2% to 2,5% of world totals. This is about the same as the airline industry users and as high as 5-6% of developed nations' total. McKinsey (2011) predicted that the ICT sector's carbon footprint would triple during the period from 2002 to 2020. The benefit of mitigation greenhouse gas emission can only grow, as more organisations, public sector institutions, households and others adopt the practices of greening technology (EPA, 2013c).

Implementing green IT is significant to support wide enterprise application in the prevention of pollution, product stewardship, sustainable and development strategies (Molla & Abareshi, 2012). Green IT solutions are actively being pursued by most of the organisations for many reasons and benefits, including the reduction of power

consumption cost, reducing carbon emissions and the environmental impact, improving systems performance and increasing collaboration and interaction (Bose & Luo, 2011).

2.6.4 E-waste and u-waste disposal management

New technologies have an opportunity for faster or easier access to information. On the other hand it has also considerable implications in the 21st century. The challenge of new technology poses a feeling that something good has happened whereas in reality nothing fundamental has changed (Mortimor, 1999). Besides, technology and electronics play a great role in everyday lives. Along with the benefits, technology has brought into attention many challenges, such the rising problems of e-waste. The environment is saturated with computing and wireless communications capability, yet gracefully integrated with human users. Almost everything these days has electronics built in. New technology is constantly being developed, which increases the need to upgrade. This also brings with it a huge amount of redundant equipment in need of recycling (Jones, 2009).

The problem with electronic waste is that it contains many harmful materials. The commonly found toxic substances listed by the study done at the University of Illinois (2009) are halogenated compounds, heavy metals (barium, mercury, lead, zinc, chromium and cadmium) and other metals, among others some of the many substances found in electronics. These substances are all harmful to the environment as well as to humans. It is important that electronic waste is appropriately recycled instead of ending up in a landfill polluting the environment. Electronic waste is a current worldwide problem that needs to be managed promptly (Sabha, 2011).

Electronics waste labelled as "e-waste" is not actually waste at all (zero-waste policy), but rather electronic equipment or parts that are readily to be resold for re-use or can be recycled for materials recovery. In fact, cell phones and other electronic items encompass great amounts of precious metals such as gold and/or silver. In addition to that, recycling electronics reduces pollution that would be generated while manufacturing a new product and the need to extract valuable and limited virgin resources or raw materials that must be mined or captured from the earth for use in the creation of products or energy (EPA, 2013b).

E-waste packs landfills with reusable or recoverable materials and takes up space needed for non-recyclable products that pose serious threats to the environment. Rapid advancement of technology have led to a constant stream of new products and causing

exploitation of rich mineral resources that contains precious and special metals, including gold, silver, palladium and platinum (Namias, 2013).

Plambeck and Wang (2009) express the view that new laws implemented overseas hold the manufacturers responsible for the recycling of their own products, which will affect human beings directly or indirectly. The responsibility is simply transferred to consumers to make sure the items are recycled correctly. Among the items of the devices that have to be recycled properly are: computers, displays, laptops, server units, printers, mobile phones, tablets and handhelds, TV screens, household electronics, and networking equipment.

Every successful organisation in this age of environmental awareness is becoming integrated with proper recycling and various green solutions. South Africa faces a number of recycling challenges when it comes to e-waste. Finlay and Liechti (2008) note that Desco in South Africa offers a socially responsible solution for e-waste management to minimize costs and take the responsible approach to reduce the need to mine more of the metals that go into high tech. Desco Electronic Recyclers commits to engender a standard of excellence by providing a high quality service for the e-waste management and ensuring that this service is always conducted in an environmentally affable manner, and that the processes involved during the disposal would at all times conform to and comply with all relevant legislations as enforced by the recognized authorities.

Technological advancements make life more entertaining and improve the way individuals work and live. Every single advancement contributes to the environmental threat as the old equipment is replaced by the new model technologies. In an average year, 24 million computers in the United States become obsolete. Only about 14% of these will be recycled. The rest, more than 20 million computers, will be dumped, incinerated, shipped as waste exports or put into temporary storage to be dealt with later (Swaminathan, 2013).

As illustrated in Figure 2-1 below, (developed and re-designed from the concept of the University of Illinois, 2009), for e-waste disposal improve, it needs the following practices and strategies: use, re-use, refurbish, repair, recycle, reduce and remanufacture the e-waste, from going into the landfill or incinerator where they can leach into the environment and become harmful. Besides, the e-waste strategy requires to test the knowledge of 1) market intelligence as well as appropriate e-waste disposal systems, 2) facts about obsolesced issue that better informs regarding the software maintenance and hardware upgrade, 3) design and flexibility issues that better inform the design of electronic devices for

disassembly and maintenance, and, finally 4) information feedback labelling design and flexibility issues, to support the accurate identification to labelling products.
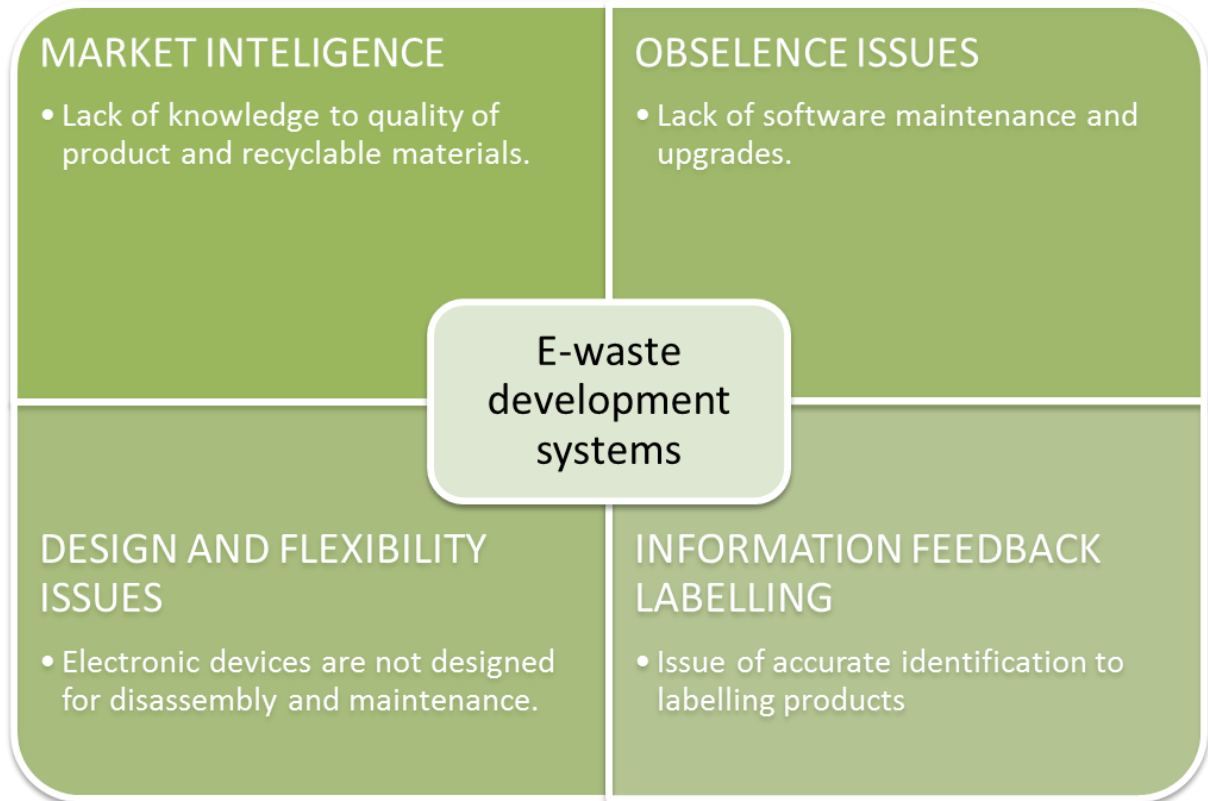
Figure 2-1: Knowledge that could better inform the e-waste disposal systems based on the concept of University of Illinois (Source: University of Illinois, 2009)

Electronic products that are considered to be hazardous are not only limited to television and computer displays. Electronic hazardous waste occurs in all computers, circuitry, circuit boards, expansion cards, hard drives, power supplies, modems, routers, keyboards, telephones and cell phones, copiers, fax machines, cables, iPods, televisions, stereo and video equipment, speakers, toner cartridges, lithium-ion batteries, routers, video game controllers, microfiche and magnetic media (Chen *et al.,* 2008; Fuchs, 2008; Sabha, 2011).

Apart from improving the utilisation and long-lasting life of existing IT equipment, deployment of e-waste has become an economic and ethical issue as millions of tons are transported to third-world nations to be disposed of. E-waste contains a large percentage of colossal toxic materials that, if not handled properly, can have adverse health effects on the surrounding population. The importance of green IT is that it is now at the forefront of technological civilization (Albertson, 2008).

The local governments and institutions of higher education in Malaysia have implemented various green computing campaigns aimed at promoting sustainable IT practices. Some examples of the measures include placing recycling wastes according to its type and classification (paper to paper, metal to metal, glass to glass) in campuses so students can drop obsolete computing hardware and related electronic devices and other resources for everyday use (Ahmad *et al.,* 2013).

2.7 Enabling optimisation of IT resources for green growth

As computers are made up of software and hardware, green IT should also be seen within these dual concepts. Having connection to each other, software and hardware need to fulfil their common mutual purpose. Without software, hardware is very limited; and without hardware, software would not be able to run at all.

Generally speaking, the optimisation of ICT resources has to look at the product design, resource depletion, and toxicity of raw materials and energy and resources required to manufacture the product and how the product can be recycled or re-used from the initiation to the decline phases of the market. In order to effectively manage the various computer equipment, examining the use of resources in production is unavoidable. Sustainable green IT is a conscious choice-making to minimize energy consumption, the carbon footprint, networking hardware and layers of software during its life cycle and use.

2.7.1 Software development optimisation

Software means computer instructions or data. Anything that can be stored electronically is software, in contrast to storage devices and display devices which are called the physical components of the computer. Software is often divided into two categories: system software and application software. Systems software include the operating system and all the utilities that enable the computer to function and direct, while applications software is a system that includes programmes that do certain tasks for users. Software development optimisation is a general term used to describe a collection of computer programmes, procedures and documentation that perform specific tasks in a computer system in a way that meet the requirements of efficiency and eco-friendliness.

As computer hardware has progressed and developed over time, so has the software. Green software largely exists to accomplish two goals: One is to make it easier to get complex data and the other is to fine-tune the control over computers, industrial equipment and to

understand and manipulate other devices (Kanellos, 2009). Green software has the capability to assist developers, administrators and computer users in realizing sustainable software engineering comprising modules for metering and visualizing resource and energy consumption, as well as modules for a context-sensitive provisioning of guidelines checklists, and modules for regulating and controlling the resource consumption of software products.

The operating systems, for instance, Windows 7, can be a lot more energy-efficient than Windows XP and even Vista. Although it may need a more powerful PC to run than XP, in tests, they both take about the same amount of power doing typical office work such as word processing. With Windows 7 there are a lot of features and strong steps on delivering and improving power of management (hibernate or sleep mode) from an OS perspective. In short, it is when the machine is not in use that most savings can be made (Appasami & Suresh, 2011).

Unlike other software industries, Apple Operating System (OS) uses power adapters that draw less power when products are not in use and makes sure that the hardware and software work together to conserve energy as efficiently as possible. Mac and Apple display not only meet the qualification but exceeds the strict guidelines for energy efficiency in the energy star specification (Apple Company, 2014). The MacBook Air, MacBook Pro, iMac, iPad, iPad mini, iPhone, and Apple have an ambient light sensor built-in to monitor the use of energy. OS X with Bonjour Sleep Proxy running on AirPort base station or Time Capsule and the Wake on Demand feature provide a network share of files, music, printers and screen with other computers even if the Mac is asleep. This saves energy while still ensuring full access to all your shared files and devices (Apple Company, 2014).

Kundra (2011) defines major aspects in addressing cloud computing with the need to provide highly reliable, innovative services quickly despite resource constraints. As highly interactive web application and data intensive software, cloud computing includes reduced cost, easy maintenance and re-provisioning of resources and telecommuting, and in so doing increases profits and saves the environment. In addition to that, cloud computing offers several advantages by allowing individuals to use services that include infrastructure, application, and/or storage space for a nominal fee. As these services are created and offered by the cloud service provider, users need not purchase additional

infrastructure for use at their own premises (servers, application programmes, operating systems, etc.).

The green IT software introduced in Japan and already used in the US, such as INFOR EAM Asset Sustainability Edition, referred to as enterprise asset management, allows a company to address in detail their power consumption and greenhouse gas emissions on a machine in machine basis. Now, with the Asset Sustainability Edition, organisations can monitor the energy efficiency of each unit of the production process from production machines to IT servers, routers, and switches on how to measure, analyse and control energy efficiency (Japan External Trade Organisation (JETRO, 2012)).

Software can play an important role in reducing the power used on mobile platforms and extend battery life. Steigerwald and Agrwal (2011) address the characteristics of green software and the software design considerations to improve software energy efficiency in getting the work done quickly (computational efficiency), achieving software algorithms that minimize data movement and designing an application software that efficiently uses cache memories.

2.7.2 Hardware development optimisation

Hardware is best described as all devices that are physically connected to the computer or peripheral (auxiliary device) that can be physically touched. Most hardware contains a circuit board, ICs, and other electronics. Hardware can be classified into five major parts: input devices (keyboard, mouth, scanner) output devices (printer, camera, video camera), processing devices (CPU, RAM, sound card, video card, mother board and so on) storage (CDs, DVDs, USB memory stick, internal and external hard drives) and network devices (modem, hub). Without software hardware is very limited and vice versa.

2.7.2.1 CRT monitor versus flat-panel displays

Monitors account for almost two-thirds of a computer's energy use. Monitors have the highest energy consumption in office environments. A typical desktop computer alone consumes from 50-250 watts of energy (Bray, 2006). Green information needs to transformation from equipment that consumes a lot of energy and is hazardous to repair and prohibits their disposal in landfill. Desktops consume significant amounts of energy and many of these devices are left on 24 hours a day, seven days a week without turning off power when not in use.

Power management is a switch to energy-saving mode to allow computers and monitors to turn off or sleep (systems standby) when not required and in low power mode during idle periods. A study made by Vanhorn (2005) illustrates that turn-off peripherals when not in use, can reduce the daily energy usage by 6,7%; turning off monitors when not in use can reduce the daily energy usage by 24,5%. Computers set to sleep when not in use can reduce the daily energy usage by 62,3%. Efficiency is thus critical, as that is where power savings come into play.

Harvard's campus ignores the excessive power use in light of competing technologies which fail to deliver on promises of power savings (energy star) and on the other hand promotes relatively high power consumption at high brightness and contrast levels and fast scan rates when compared to different displays such as: CRT (Cathode Ray Tube), LCD (Liquid crystal display), OLED (Organic light-emitting diode) and Plasma display (Porter & Kramer, 2006). Harvard's campus encourages manual power management, which relies on educated users to turn off their computers. Manual power management can achieve impressive results with ongoing education and reinforcement.

Vanhorn (2005) states that LCD monitors use 40% less energy than equivalent-sized CRTs despite being bulky and heavy. Besides, the sizes of the screen consume a great deal of energy, as the higher the resolution is, the more energy it needs. A 19-inch monitor uses 40% more energy than a 17-inch monitor. Cornel University recommends only buying monitors as large as the student or the lecturer really needs. The Global Executive Director Sustainability of Fujitsu, Rowe (2011) demonstrates that desktops contribute 43% of the IT emissions profile. Replacing CRT with LCD displays can save energy costs. Besides, they are flexible, simple, and produce less heat.

As of 2012, most implementations of LCD backlighting use Pulse-Width Modulation (PWM) to dim the display, which makes the screen flicker more acutely than a CRT monitor, as 85 Hz refresh rate would, causing severe eye-strain for some users. Unfortunately, many of these users do not know that their eye-strain is being caused by the invisible strobe effect of PWM. This problem is worse on many of the new light-emitting diode (LED) backlit monitors, because the LEDs have a faster turn-on or turn-off time than a CCFL bulb (Delphi Display Systems, 2008). The new generations of products, such as computers, screens and mobile infrastructure equipment have led to an average 30% power-consumption efficiency gained in three years through environmentally friendly design and development (The Editors, 2009).

2.7.2.2 Uninterruptible Power Supply (UPS)

UPS is used in the event of power system failure to maintain power during unexpected power outages. The failures can vary from something as little as small power interruption to a large-scale, long-term power outage. Momentary failures can be caused by wind (storms), lightning, rodents coming in contact with overhead power lines and vehicles striking utility poles (Avelar, 2011). These types of blips can cause the voltage to sag below a point where most sensitive electronic equipment will be affected.

As Avelar (2011) re-states, more severe outages can occur as the result of storms or other natural and man-made catastrophes such as equipment failures, transformers and high voltage cables. These types of outages tend to last anywhere from several minutes to several hours, if not several days. UPS system needs to be designed with the type of outages that the users are likely to experience, in mind. Selecting the effective and power saving UPS among the different types of UPS such as Standard by Power System (SPS), Line Interactive System and On-Line Double Conversion System (AC to DC, DC to AC) are vital issues on greening hardware.

Due to an increasing environmental awareness, CyberPower has introduced an uninterruptible GreenPower supply technology that reduces energy costs and equipment. CyberPower is committed to leading the UPS industry in green UPS designs by reducing the heat generated and energy consumed during a normal utility power operation. According to the 2007 Frost and Sullivan UPS Industry reported by Minn (2008), several million UPS units under 5k VA UPS are sold in Latin America at a value of $1,6 billion. Consequently, the cumulative cost-savings to customers, energy-savings, and reduction in environmental impact is truly remarkable. Green data centres need to use low-powered blade servers and more energy-efficient uninterruptible power supplies as they use less power than a legacy UPS.

2.7.2.3 Desktop and server virtualizations

Virtualization is a technology by which hardware resources are separated from the operating system and applications by a software abstraction layer. In other words, it means that multiple under-utilised computers can be virtualized into a single physical computer and achieve a more rationalised distribution and utilisation of the various resources. Organisations adopt virtualization mainly for better hardware utilization and cost

reduction. With a reduction in operational costs, virtualization can also help organisations to be perceived as greener and socially responsible corporate entities (McCabe, 2009).

With desktop virtualization, each user gets a virtual machine that contains a separate instance of the desktop operating system and whatever applications have been installed. Compared to server virtualization, the adoption of hosted desktop virtualization has been relatively slow so far. Even though desktop virtualization does not offer a lot of benefits in terms of power consumption, it does help in increasing the operational life of the desktops as higher processing power requirements can be met by the virtualized desktop (Chitnis *et Al.,* 2011). The advantage of having desktop and server virtualization is an optimal resource usage, better application security, stability, flexibility and performance. Above all, virtualization also helps reduce the ecological impact at all stages of the computer lifecycle.

According to the EPA (2007), implementing best energy management practices in existing data centres could reduce their current energy usage by from 30% up to 70%. A reduction in energy usage could be achieved by using high efficiency technologies for cooling and power equipment and virtualization techniques. Server virtualization, server optimisation and storage virtualization, eliminating server sprawls and consolidating computing resources into a larger data centre can benefit reducing power consumption and boost performance per megawatt.

Knorr and Gruman (2008) explicate that cloud computing that runs on virtual machine bases, eliminate the need for hardware from being bulky with "virtual" servers or server in cloud by computing systems that are based on the same objective of sharing heterogeneous computational resources.

2.7.2.4 Central Processing Unit (CPU), memory and storages

As demonstrated by Horowitz (2003), a conventional desktop computer with a conventional cathode ray tube (CRT) monitor uses five times as much energy as a laptop (570 kWh/yr vs. 100 kWh/yr). A typical laptop computer has a maximum power consumption of 15 watts and extensive power management capabilities, while a typical desktop PC with display consumes about 10 times that and has limited power management features. Buying and using a laptop instead of a desktop computer or using CPU that promotes energy star has an advantage on greening the use of technology. The "Energy Star" labelled devices can be programmed to "power down" to a lower power state when

they are not in use. This helps save energy and run cooler which then results in the devices lasting even longer.

Electronic devices, such as computers, cell phones, digital cameras and chargers draw power even when they are switched off or not in use, just by being plugged in (Horowitz, 2003). Unplugging devices or using a power strip that enables the computer accessory to turn off at once when they are not in use cuts back power. In addition to that, switching from desktop to energy-saving computers such as laptops and thin clients gives an advantage of using far less energy than the high amount of energy required by a desktop (Lee *et al.,* & Fan, 2004).

Netbooks and other thin clients use about half the power of a traditional desktop PC. They are smaller, cheaper and simpler for manufacturers to build than traditional PCs or notebooks (Bray 2006). The thin clients use very little energy. In fact, a typical thin client uses less power while up and running applications than an Energy Star compliant PC uses in sleep mode. Thin clients are also ecologically friendly because they generate less e-waste. There is no hard drive, less memory, and fewer components to be dealt with at the end of their lifecycles (Queen Margaret University, 2009).

The study conducted by Smith (2013) on major banks of Australia shows that the carbon emission from 20, 000 computers using 868kW of electricity each year, equals 12, 467 metric tons of CO_2. This much CO_2 is equivalent to the: 1) annual greenhouse gas emissions from 2, 384 passenger vehicles; 2) CO_2 emissions from 28, 994 barrels of oil consumed; 3) CO_2 emissions from the electricity consumption of 1, 619 homes for one year; and 4) CO_2 sequestered by 2, 658 acres of pine or fir forests.

Electronics Take Back (2014) demonstrates that manufacturing one PC takes a minimum amount of 240 kgs fossil fuels, 22 kgs chemical components and more than 1, 5 tons of water. PC fleets and peripherals take 31% of the global ICT energy use. Roughly, today over one billion PCs are used globally, and that is expected to increase to 4 billion by 2020 (Rowe, 2011). A study done at Stanford University (1996) shows the amount of resources and energy consumed as measured as a ratio against the weight of the final product (chip) is one of the highest amongst all manufacturing industries.

2.7.2.5 Printers

The printer is one of the most useful tools in an office workplace. It is also one of the biggest energy users of all computers accessories. All-in-one printers consume much more

energy than traditional printer, as they are much more functional. Green printers are committed to bringing individuals the most environment-friendly services available in printing. Green printing refers to the practice and promotion of environment-friendly printing and the reduction of paper usage (Ponte, 2013).

Energy can neither be created nor be destroyed, but conserving energy is far most important. Green printer practice also includes reusing recycled paper, switching to vegetable or soy-based ink, recycling paper waste and ink cartridges properly, and using software regulations that get rid of unnecessary content when someone prints. Ponte (2013) identifies that laser printers use a significant amount of energy while printing. He encourages buying eco-friendly ranges of resources (desktop, laptop, printer, scanner, etc.) which will also help reducing the e-waste as well as implementing direct practical measures with existing hardware and software to minimise the carbon emissions resulting from printers use.

2.7.2.6 Game consoles, digital devices and various other gadgets

The majority of people in developed countries are likely to have a computer, a games console, or a TV; and many times they will have all three or even multiple computers and TVs. Besides the devices for games, used CD's and DVD's in games are usually trash in an improper way of waste disposal (Lee *et al.,* 2004). Regular discs contain polycarbonate plastic and aluminium, while recordable CD-R's have about 20 mg of gold that can be recovered.

Rowe (2011) asserts that even more energy is consumed by gaming consoles and games played on arcade machine far from datacentre. Upgrading to video cards to get bright vision, fast accessibility and less energy consumption is indispensable. Once again Rowe (2011) asserts that ATI and nVidia's latest cards are becoming more powerful and efficient than just being practical. For example, nVidia's new 9600GT performs marginally better than that of their older 8800GT, yet uses approximately 10% less power.

Even though computers have changed the way of life and made it easy and quick to perform different tasks, the use of computer fails to have a positive impact in education. Students play games and chat for a long period of time. This causes wastage of time, money and energy (Woldu, 2009). New generations are currently spending more time on the social media websites such as Facebook, YouTube and Twitter to interact with their friends all day long through smartphones, computers and tablets, which is bad for both

their studies and their health. The longer period of time and improper use of computers can results in injuries or disorders of hands, elbows, wrists, eyes, necks and back.

2.7.2.7 Mobile or cellular phones

Today's mobile phones have multi-functionality on browsing the Internet, texting chats, playing gaming, interacting with social networking, downloading and uploading documents, including desktop computing managements. It has long RAM memory space built-in and extended storages, working at a very high speed and with wireless connectivity. According to Aggarwal *et al.* (2013), the mobile phone has also an advantage of enabling the carrier to have video conversations (conferences). Not only that; it is also easier for most businesses to attend meetings around the world, as it does not require going to the office (travel reduction). This helps the environment in reducing the amount of people using transportation which leads to worse air pollution. In addition to the advantage of being able to provide efficient service, mobile phones consist of various important materials (copper, silver, gold and palladium) that can be recovered from the recycle if they are trashed in a proper way. Besides, from mobile phones being more energy-efficient, they consume much less power compared to computers (Aggarwal *et al.,* 2013).

However, mobile phones also have disadvantages if they are misused. Mobile phones and smart phones contain hazardous materials such as mercury, cadmium, nickel and gallium arsenide that contaminate the environment if discarded in landfills. Phones donated for goodwill are kept out of landfills and are either refurbished and sold or scrapped for parts or recycled (EPA, 2013b). When unwanted cell phones are landfilled, these chemicals leach into groundwater; and when they are incinerated, the toxics contaminate the air.

Research done in Finland by Radiation and Nuclear Safety (2009) indicates that mobile phones have an impact on health. People who sleep next to their phones may develop a brain tumour due to the radiation that is given off by cellular phones. Not only does the cause of the radiation affect human beings, 0'345678 also when the phone is trying to find a signal it affects the fourth stage of human sleep (a deep sleep that lasts for approximately 30 minutes).

2.7.2.8 Telecommuting and web conferencing (teleconferencing)

Telecommuting first gained popularity in the late 20th century with the beginning of personal computers and advanced telecommunication technologies. Comprehensive

research on the practices of telecommuting was introduced in the 1970s when Jack Nilles, the father of telecommuting invented the terms "telecommuting" or "teleworking" and directed his first telework demonstration project with limited funding from the National Science Foundation (Hamilton, 2003).

"Telecommuting" refers to the activity of performing one's job through the use of Information and Communication Technologies (ICT) in a location that is different from one's physical location (Thomas, 2014). This whereabouts may be home, a telecommuting centre, a client's office, or a hotel room. Regardless, the concept remains the same. IT allows people to have a rich media experience with those with whom they work, eliminating the need, at least some of the time, to transport oneself. There is no need, to be in the same room as one's co-workers.

Consider the environment-friendly change in a country such as the United States of America, which contributes about 25% of the world's CO_2 to the atmosphere annually, 20% of which is from driving cars, and 16% from commuting, making the American commuting responsible for roughly 1% of the world's annual CO_2 emissions (Toomey, 2008). Furthermore, as sprawling continues to envelope the countryside surrounding the major urban areas, public transportation systems have not kept up, with that development and the distance between worker and workplace continues to grow.

McCabe (2009) demonstrates that the American Electronics Association estimates the conservation of billion gallons of gasoline yearly, if every American worker has the ability to telecommute via web conferencing instead of travelling to meetings (teleconferencing). Web conferencing is a great way to go green and save huge amounts of time and money. Virtual private networks and collaboration tools such as HyperOffice and IBM LotusLive help staffs to work together from different locations and improve resource utilisation, reduce energy costs and simplify maintenance. Computer companies such as Dell, HP and IBM each offer a range of comprehensive server and storage virtualization solutions and services.

An estimated 50 million people currently work at home at least part of the time (Thomas, 2014) as the number of teleworking grows and computers become an important part of the home working scene. Telecommuting in its many forms is emerging as a significant social communication medium and economic trend. Thomas (2014) asserts that more than 15 million people telecommute two or three days per week. The annual survey by the Society

for Human Resource Management also found a greater increase in the number of companies planning to offer telecommuting in 2014 (Society for Human Resource Management, 2014). Thus telecommuting is becoming one of the most talked-about business office scenarios. According to Hamilton (2003), telecommuters are less stressed, less likely to call off from work, more efficient and greener. Besides, it reduces costs for both employers and employees and can also reduce the spread of contagious diseases.

2.8 Green procurements and policies

Green procurement entails purchasing products and services that cause minimal adverse environmental impacts. It includes human health and environmental concerns as well as its need for high quality products and services at competitive prices (Aggarwal *et al.,* 2012). Specifically, it encourages people to avoid single-use disposable items, and rather purchase products. Green procurement policies are applicable to all organisations, regardless of size.

Many organisations worldwide have initiated energy-management programmes, such as Energy Star, an international standard for energy-efficient electronic equipment that was created by the US Environmental Protection Agency in 1992 and has now been adopted by several other countries (Gingichashvili, 2007). The policy behind Energy Star is to promote and recognize energy efficiency in monitors, climate control equipment, and other technologies, for instance, automatically switching it into "sleep" mode when not in use or reducing the amount of power used by a product when in "standby" mode (Vanhorn, 2005). Energy Star is a joint programme of the U.S. Environmental Protection Agency and the U.S. Department of Energy to protect the environment through energy efficient products and practices. There are strict guidelines that must be met, and only a limited percentage of products are accepted into the programme.

The University of Illinois (2009) purchases computers and laptops exclusively from Dell because it complies with green procurement policy. The Dell Company designs and engineers its products to help prevent pollution and conserve natural resources throughout the system's life. Reducing the environmental impact of Dell products begins at the design stage. Cross-functional product design teams work to make thoughtful and effective decisions that will have positive environmental results throughout the equipment's life cycle analysis.

IBM and Sun Microsystems are among the few IT companies that have embarked on the program of training and certification of partners on green technology and services.

(Kiruthiga & Kumar, 2014). There is also valuable information on the subject of going green available on the official website of Cisco. The Sun's Eco Advantage Program is an example of green procurement which involves training partners who sell the company's SPARC (Scalable Processor Architecture) systems on data centre energy consumption and cooling, including the delivery of consolidation and virtualization services (Kiruthiga & Kumar, 2014).

The TCO (Tjänstemännens Central Organisation) Certification Programme to promote low magnetic and electrical emissions from CRT-based computer displays is administered by TCO Development, owned by the Swedish Confederation of Professional Employees. This programme was later expanded to include criteria on energy consumption, ergonomics, and the use of hazardous materials. TCO Certified is an international sustainability certification for IT products and includes a wide range of criteria ensuring that the manufacturing, use and recycling of IT products is carried out with regard to environmental and social responsibility. TCO Certified combines requirements for social responsibility at the facilities where the product is manufactured, and user safety and ergonomic design, as well as minimal environmental impact for both the product and its production during the whole life cycle (TCO Development, 2012).

Many corporate IT sectors have green computing policies to reduce the environmental impact of their IT operations. The Electronic Product Environmental Assessment Tool (EPEAT, 2014) is an environmental procurement tool designed to help institutional purchasers compare and select desktop computers, laptops and monitors based on their environmental attributes. EPEAT meets an extensive list of environmental lifecycle-based criteria covered in the IEEE1680.2: Standard for Environmental Assessment of Imaging Equipment, to assist in the purchase of "greener" computing systems.

Likewise, the Green Grid is a global consortium dedicated to advancing energy efficiency in data centres infrastructure efficiency (DCIE) among different business computing ecosystems such as AMD, APC, Dell, HP, IBM, Intel and Microsoft. The Restriction of Hazardous Wastes Directive (RoHS), restricts the use of lead, mercury, cadmium, chromium VI, PBB (flame retardant), and PBDE (flame retardant) materials in electronic equipment.

Policies that encourage the protection of the environment are continually being developed nationwide (Brunoro, 2008). Universities can assist in protecting the environment by

adopting technology standardisations and green procurement practices. According to the Verdiem Corporation (2008), sustainability has become a major focus for organisations, as it has been discovered that sustainable practices can strengthen reputation, improve employee morale, lead to cost savings and benefit the environment.

2.9 Critical review of the literature studies

Green IT can be an important and strategic decision for many internal and external organisations. Sustainable green IT can influence organisations stakeholders, especially those seeking to introduce green IT into their organisations. The literature review has unveiled an investigation and means of tools based on different critical reviews for the evaluation and judgement of its worth over all the strengths and weakness of the systematic literature review.

The previous review of the published literature has identified how sustainable green IT has significantly enabled and transformed organisations in many important ways (Watson *et al.,* 2010; Pitt *et al.,* 2011; Howard, 2014; Besson & Rowe, 2012), and how much current debate goes on around the question of whether the side effects of technology outweigh the benefits (Molla, 2009; Molla *et.al,* 2011; Murugesan, 2013). However, prior research does not clarify and specify the issue of educational green sustainability in particular. There is an initiative but not in-depth body of knowledge in higher education institutions, specially related to ensuring sustainable measures of practice for radical transformation to mitigate environmental impact.

The literature review provides many references and concepts towards environmental depletion and damage, and its resultant threat to the future of many societies (Carnagie *et al.,* 2008; Chevron Company, 2011; EPA, 2011; EPA, 2013a; European Commission, 2013). It also provides claims that climate change is not just a natural phenomenon, but is also significantly influenced by human activities. A frequently occurring subject is anthropogenic issues to address climate change and global warming. This is mainly caused by atmospheric greenhouse gasses (GHGs) and has an awful significance for the human race.

The literature draws human-related environmental problems on issues such as: air-related, land-related, water-related and technology-related environmental problems (Anderegg *et al.,* 2010; Boston Consulting Group, 2013; Carnagie *et al.,* 2008; Carvalho, 2011; Ekins *et al.,* 2003; EPA, 2011). It has also noted that the exponential growth rate of the human

population makes solving environmental depletion and damage problems more complex. Furthermore, the literature conveys the notion that IT played an essential role in society and is a critical factor for economic growth (EPA, 2013b) by improving: energy-efficient IT architecture, smart metering, alternative power supply to save energy and designing IT equipment such as green PC, thin client, Server Virtualisation, Storage Virtualisation, Teleconferencing, green printer, enhanced data centre and cloud computing.

Based on the problem definition in section 1.4 and the objectives of the study in section 1.5, the researcher conceptualises grounded theory investigation into measuring sustainable green IT practices in universities of South Africa. Grounded theory research has been published in the major journals of IS & T and the methodology has gained enough support to have its own special interest group within the Association of Information Systems (Markus, 2007). Hence, grounded theory is not restricted to the realms of sociology or psychology, but as a method of research is viable for application to a number of disciplines.

Grounded theory is useful for areas where no previous theory existed (Bound, 2011). It incorporates the complexities of the organisational context into the understanding of phenomena, and the method is uniquely fitted to studying process and change. Eventually, this study leads to the creation of a framework which may be used for adopting green IT practices.

The study is problem-based and does provide practical solutions to actual education-related problems. It is a theory and aims to contribute to the body of knowledge in the field of IT. The framework provides theoretical sampling for data gathering, including different collection techniques and data types. The aim of the theoretical sampling is to generate 'different views' or vantage points from which to understand a category and to propose theories that are primarily and strongly connected to data collected in a substantive field.

The researcher used the three phases (problem definition, data collection and analysis, theoretical formulation) developed by Glaser and Strauss (1967) to develop theoretical sensitivity and find the research proposition and integrative ways to compare it with emergent theory and make the substantive theory more valuable. The first phase is problem definition while the second phase is data collection and analysis and the final phase is theoretical formulation respectively.

2.10 A conceptual framework for measuring sustainable green IT practices based on the literature review

A theoretical framework is a conceptualisation of a certain complex research phenomenon, including the salient constructs and their interrelationships (Levy & Ellis, 2006). This framework is intended to highlight the link between varied conceptions of impact and the research methods considered applicable for investigating the topic. The objective of a theoretical framework is to enable comprehension and expose the theoretical foundations of multifaceted research phenomena through graphic explication (Webster & Watson, 2002). The sensitising theoretical framework developed from the systematic literature review presented four major backbones of sustainable green IT. These parts are: 1) e-waste and u-waste disposal management, 2) energy efficiency and energy-conservation practices, 3) technology resources optimisation assessment, and 4) socio-economic relevance. Remarkably, the scarceness of the informing theoretical framework, centred on the literature, further discloses the need for this study to empirically clarify, the practice of green IT on educational business background for environmental sustainability.

The first part, e-waste and u-waste disposal, highlights how e-waste can assist the university to reduce operating expenses, recover maximum value from electronics' incineration, landfilling, and prevent chemical leeching at the end of life so that the material can be used again (re-use), quantify the environmental benefits of proper electronics recycling and communicate these through social responsibility and sustainability reports.

Briefly, the first part, e-waste and u-waste disposal contains concepts of a) assessment of equipment life cycle and techniques, b) methods and practices of e-waste managements; c) protection and conservation of the loss of a natural resource, and finally, d) evaluation of its toxin substances.

The second part, energy efficiency and energy conservation management, deals with the reduction of power consumption and greenhouse gas emissions by a) improving energy efficiency within the establishment, b) creating alternative methods other than renewable energy generation, c) implementing IT architecture using innovative IT systems; for reduction of power consumptions, mitigation of greenhouse gas emissions, as well as conserving natural resources that excludes use of recycled inputs in production process. The rise in both energy costs and energy usage means that power consumption of the IT

process is becoming much more noticeable. Energy-conservation and efficiency improvements are the cheapest way to close the gap between energy demand and supply.

The third part, technology optimisation assessment for eco-efficiency, represents sustainable green IT designs and uses, which is a vital carrying capacity of technology optimisation such as green PC, thin client, green server and storage virtualization, teleconferencing, green printer, green stationery, green data centre and cloud computing. This stage allows the use of innovative and clean solar energy technology, proper recycling of the product and accordingly, promote safety and health concerns to minimise toxic compounds (hazardous waste) and more.

Despite innovations, energy consumption is also rising, as increased processing power means hotter processors, which means more cooling is needed. In very many cases, technology optimisation assessment indicates that the IT sector requires ways to bring greener technologies and more environmentally responsible strategies to their organisations, as well as the IT measurement equipment, the data repository, the reporting mechanism and the mitigation techniques that make sustainability possible.

The final part, socio-economic relevance examines the cost reduction and operational benefit in relation to money, time and resources. It presents a review that can contribute to identifying the costs and benefits associated with the implementation of sustainability. The benefit occurs in reducing pollutants and waste materials in organisations, industrial manufacturing, companies and business sectors, as more IT professionals are put under pressure to ensure their IT investments are made in all the right places.

The cost reduction analysis will focus especially on profitability by using environment-friendly operating processes, find green alternatives for harmful products at the same or an improved level of the performance management system, at lower cost and considering input costs in terms of regulations, energy use, service and product. The socio-economic relevance also clarifies the markets in which these products are produced and are growing rapidly, as many parts of the world cross over to the other side of the 'Digital Divide'

The sustainable green IT practice framework also contains activities and mechanism of metrics such as ensure, re-use, reduce, recycle, enforce, implement, use, utilise, adopt, accept, develop, empower, focus, invest and gain. Eventually, the entire framework consists of students and academic staff members who will use the system to carry out the tasks for which it will be used and the environment in which it will be used; as well as, the

organisational and environmental aspects of the user's task and the technical constraints of the system; with what they know, what they do, what they believe in and what they feel.

Figure 2-2 illustrates a conceptual framework for measuring sustainable green IT practices in attempting to answer the general problem statements based on literature reviews.
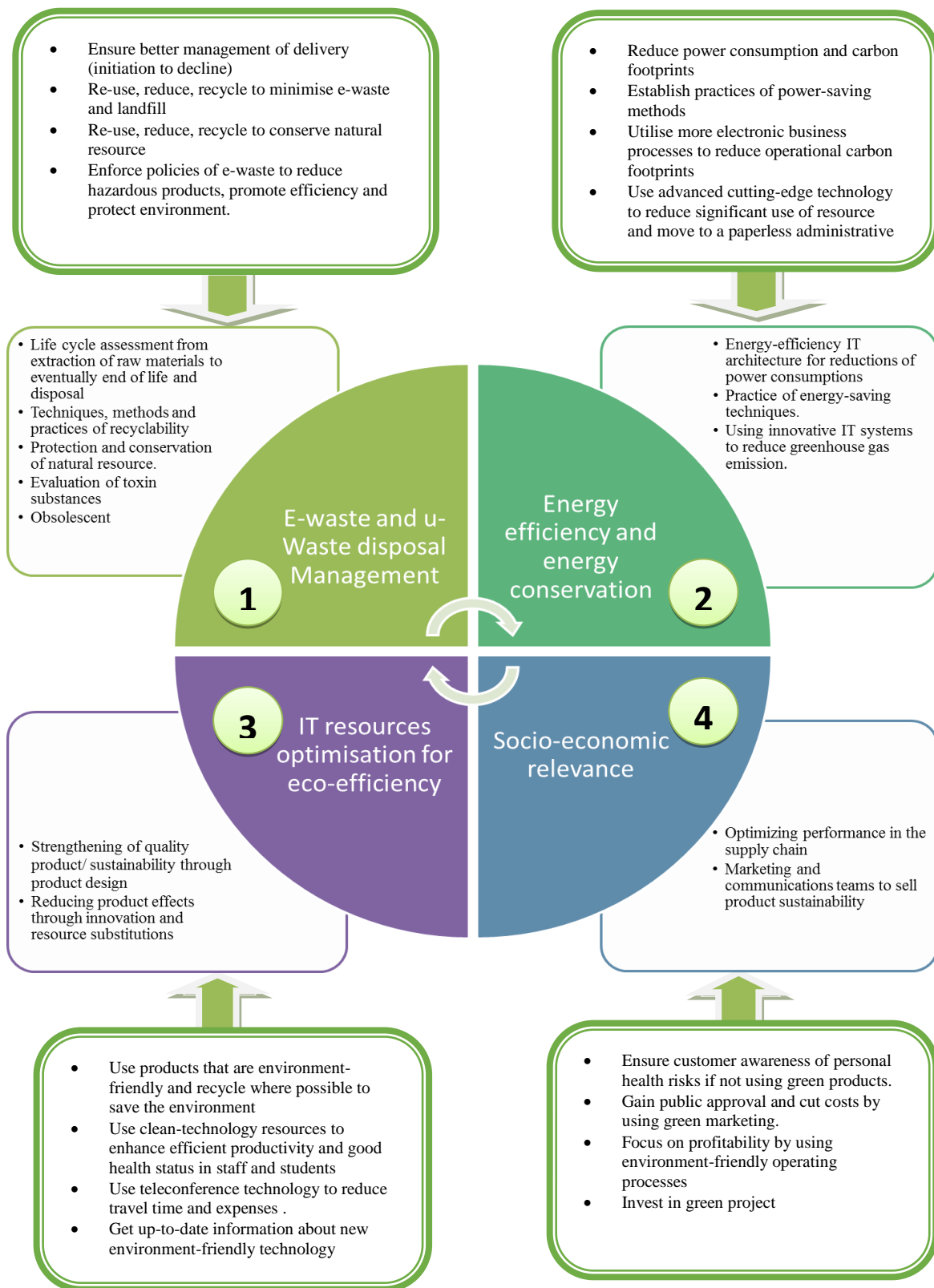
Figure 2-2: A conceptual framework for measuring sustainable green IT practices that deals with the general problem statement

The effect of sustainable green practices demands an in-depth knowledge of students and academic staff harmonisation, together with the ability to satisfy these requirements while contributing to environmental sustainability. The general conceptual framework for measuring sustainable green IT practices is classified into four major sub-classifications that assisted the researcher in grouping the functions into four logical groups so as to exclude duplication of activities, as well as to simplify the analysis of the empirical results. The functions were grouped as follows:

2.10.1 A framework on the impact of e-waste disposal practices

The e-waste disposal should be seen in relation to a life cycle assessment (LCA). The life cycle of a product comprises three measures of things such as production, use and disposal phases. When universities are considering using a material as part of green renovation, there are several factors they must bring into consideration. For instance, how much embodied energy (energy expended in the manufacturing process) do products contain? How do products affect the indoor air quality of the environment? Are the products recyclable after they have been served? Briefly, a life cycle assessment allows to determine whether a material is truly sustainable from the initiation phase to the decline phase, including the extraction of raw materials, manufacture and processing, transportation, installation and maintenance. A life cycle assessment is the cradle to grave quantification of potential environmental impact of products or services.

Figure 2-3 depicts four phases of practices that should be done in the reduction and improving the disposal of e-waste. These are assessment in manufacturing, packaging and shipping, operational and disposal. All these phases respectively have to compare the environmental impact throughout the upstream and downstream processes associated with the production and optimise processes with regard to ecological aspects, evaluate the environment-relevant aspects of transport processes, and provide support with environmental reporting and certification (EMAS II and III, Product certification, environmental product declaration).

The environmental issue of computer use is mostly not recognized or taken into consideration by the users. It is significant to monitor closely and understand every phase of the of the computer's lifecycle, as their impacts are visible in the manufacturing phase, use and discarding of computers used in higher education institutions (Adamson *et al.,* 2005). Through this practice universities can save precious energy, time and money spent

in manufacturing, packaging, operation and disposal of these electronic items. Resources used and money spent in these four phases from scratch are far greater than those needed for recycling it.
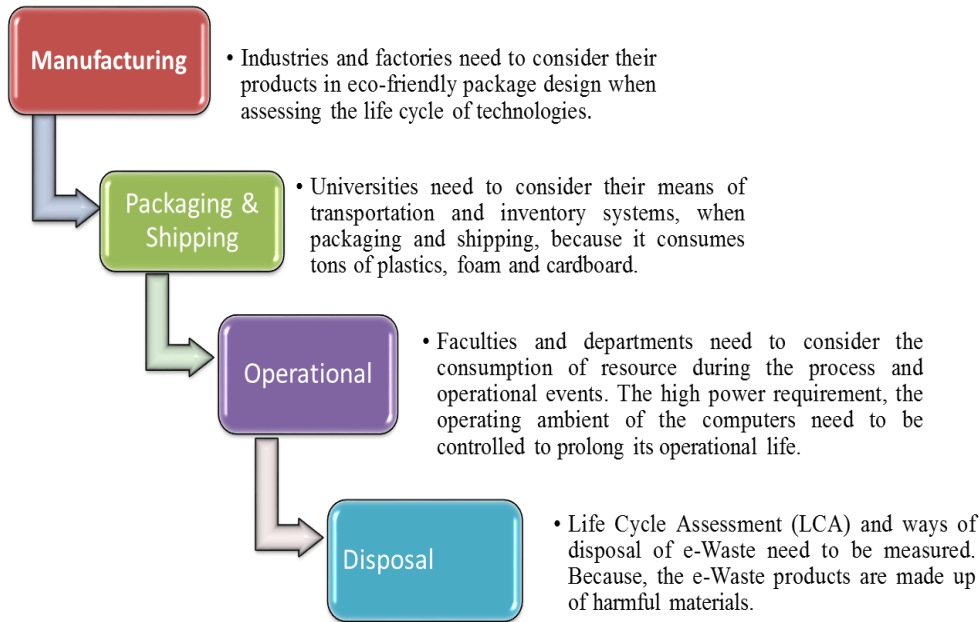
Figure 2-3: A framework on the impact of e-waste disposal practices

2.10.2 A framework on the competence of practices in energy efficiency and greenhouse gas emission reductions

Energy-efficiency programmes have been operating successfully across many different countries since the late 1980s (EPA, 2007). There is a strong rationale for the International Energy Agency's (IEA) engagement with cities and local governments on the issue of energy efficiency (IEA, 2007). Energy efficiency can enhance the health and wellbeing of both students and staffs at the university by reducing greenhouse gas emissions, improving outdoor air quality and decreasing acid rain.

On the other hand, the practice of energy-saving techniques (power management features, promoting labelling of Energy Star qualified product, purchasing of energy-efficient and less hazardous products and equipment) offers cost-effective opportunities for achieving business cases. The rise in both energy price and power usage means that the power consumption of the IT process is becoming much more obvious. Even if universities are

incapable to directly measure their IT power consumption, they are often conscious that it is extremely high and should be lowered if possible.

By achieving their sustainability goals, universities can enhance optimisation while controlling high costs through lower energy bills and automated information management systems. Further savings are generated by liberating resources from labour-intensive manual processing. It is unquestionable: sustainability is an essential part of a university's business strategy, but pertinent public and private institution sectors seem to be spending most of their time and money producing a sustainability report rather than implementing change in actions.

When discussing the concept of energy efficiency, we need to remember that heat and energy are interrelated and have much commonality, and it is not that easy to distinguish between energy efficiency and carbon footprint reduction. Though they are two distinct entities, they are not completely separated elements. Energy appears in many forms and is often expressed in multiple units (Kilowatt or Joule). Energy is used for heating or lightening the darkness or even moving heavy machines such as driving a car or flying an aeroplane. In other words, where there is energy there is always heat, and where there is heat, there is always carbon footprints too.

Carbon footprint is a term used to describe the amount of greenhouse gas (GHG) emissions caused by a particular activity or entity and is thus a way for universities and individuals to assess their contribution to climate change (Herrmann *et al.,* 2012). Increased energy efficiency can lower greenhouse gas emissions and other pollutants. Energy efficiency can also boost the local economy and create downward pressure on natural gas prices and volatility (EPA, 2007).

This pictorial framework of the impact of energy efficiency and greenhouse gas emission reductions in Figure 2-4 focuses on three main key-metric measurements and practices such as reducing, saving and improving. An effective green IT practice should clearly identify the reduction of the impact on greenhouse gases' emission and energy consumption rather than expanding the use of information technology. Green IT could be seen as just a means to reduce what McKinsey's research (2011) estimates will be 3% of worldwide greenhouse gas (GHG) emissions in 2020. Likewise, a green IT practice ought to achieve a drastic saving of energy consumption for entire network systems, including data centres, by improving the production, distribution and usage of energy efficiency.

Reducing:
- Energy consumptions
- Carbon footprint emissions.
- Consumption of natural resources

Improving in technology:
- For using conventional sources of energy (renewable energy) such as windmills, wind energy, biomass, solar etc.
- In designing cutting-edge products.
- In designing efficient, innovative, flexible, portable and less spaced packages

saving

reducing

Improving

Saving:
- Using renewable energy
- Switching from energy-intensive products
- Accrediting star ratings on appliances & devices
- Configure & adjust devices to low-power mode (standby power or battery-life indicators)
- Unplug or shut down when devices are not in use
- Comply with all applicable environmental policy statement

Figure 2-4: A framework that depicts keywords for means of practices of energy efficiency and greenhouse gas emission reduction

Heating and cooling systems account for a significant portion of the energy consumption of a building. Cooling and dissipation of heat, especially around the CPU, is often a cause for concern, as the temperature of the internal part of a PC rises due to the amount of heat generated by the CPU. However, it is possible to lessen this impact in both central and unitary systems by increasing their efficiency. Cooling systems generally have higher space-conditioning capacities than heating systems, because waste heat from people, lighting, and office equipment supply a large portion of a building's heating requirement. Although their higher capacities usually translate into more opportunities for savings from cooling systems, savings can still be had from heating systems. Many existing systems are oversized to begin with, so it may now be possible to justify replacing the current system with a properly-sized one. Apart from choosing the right sized and cooling devices for PC, there is a possibility of increase in the lifespan of the components, avoid overheating, and

improve reliability by taking measures of practices such as maintaining a clean, dust-free operating environment.

2.10.3 A framework on enabling green technology software and hardware optimisation and operational practices

Green IT optimisation performance refer to the study and training in using technology and IT resources in a more efficient, effective and environmentally responsible manner. Computers and computing processes consume quite a lot of natural resources for manufacturing, energy to run the system, and the problems of disposing at the final phase. Whether it is massive or small, all organisations, without exception, are dependent on technology. In the operational process, most universities waste resources in the form of energy, paper, money and time. These include building computers with more environment-friendly materials, designing them to consume less energy, providing recycling programmes to dispose of obsolete systems, developing the virtualization and cloud computing alternatives, and providing tips to help students and academic staff minimise their environmental impact to go green.

Molla and Abareshi (2012) emphasise that the impact of Information Technology (IT) on eco-sustainability can be classified into two groups of first and second consequences. The first demand refers to the negative environmental effect of IT production, use, and disposal. This standpoint considers IT as negatively impacting eco-sustainability. The second consequence refers to the optimistic impact of using IT on business and economic processes. This viewpoint considers IT as part of the solutions to eco-sustainability. Each stage of the IT life cycle, from the initiation phase to the usage and decline phase (disposal) poses environmental problems (Molla & Abareshi, 2012).

Renovation, the IT architecture that is presently used, should demonstrate that it is valuable in the long term. It is not just about undertaking a set of best practices, but also about renovating the architecture as a whole. A strategy requires to be invented for the development of sustainable technology. This method is not restricted to the changing architecture of data centres. In fact, business operations, IT facilities, communication technologies and many other aspects of computer multidimensional usage need to be taken into reconsideration. For instance, one can reduce the number of systems being used and increase their efficiency. Green technology usage practice is a kind of long-term approach in which the currently used "green" initiatives might change with time. Increasing the

framework density through virtualization necessitates the installation of cooling systems, which again increase the cost and energy consumption, while changes in the architectural designs increase the accessibility to sophisticated technologies that cause minimum harm to the environmental resources'.

Computers can be made to reduce electricity by using a lower power processor, opting for on-board graphics instead of separating a graphic card, using passive cooling instead of energy consuming fans, and a solid state drive (SSD) in place of a spinning hard drive as the system disk. A great many hazardous chemicals, including lead, mercury, cadmium, beryllium, brominated flame retardants (BFRs) and polyvinyl chloride (PVC) are used to make computers. By reducing the use of such substances, hardware manufacturers could prevent people being exposed to them, as well as enabling more electronics waste to be safely recycled. As to hardware, the same method can be used to measure, reduce carbon and offset the emissions resulting from their computer use over software systems too. The following diagram in Figure 2-5 examines the hardware and software greening aspects:
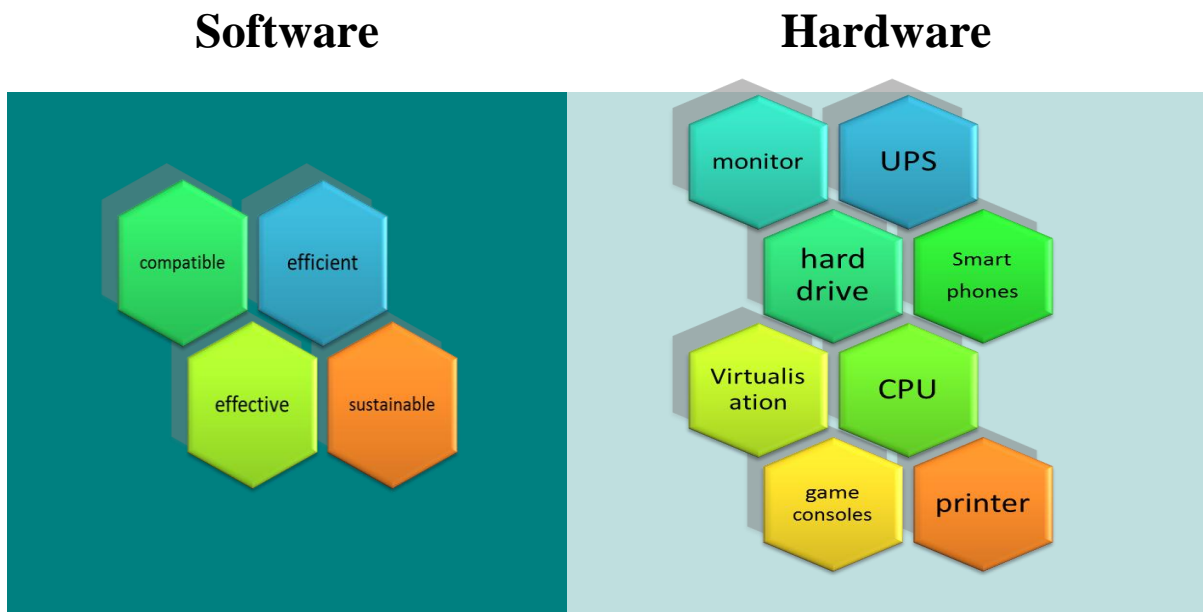
Software   Hardware

Figure 2-5: A framework that examines green software and hardware optimisation

2.10.4 A framework aiming to develop green IT practices in business and the profitability aspects of the organisations

After the implementation of sustainability and/or sustainable design initiatives, universities can review whether the expectations and requirements of those students and academic staff have been met as envisioned. Feedback and criticism from students, academic staff and other competitor parties is an important information source for the universities to improve its current or future products and services. Universities need to establish a set of performance indicators to assess progress over time in reducing environmental impact in their facilities, products or services.

With regards to the way each university conducts its business, there are plenty of opportunities and impact to consider and reduce the environmental footprint while increasing the value of optimised offerings of revenue of cost and reduction of risks. The measure for green IT practices requires an in-depth knowledge of user requirements which that supply comes from (products) or whether the system is applied to the exclusive use of authorisation (service evaluation) to reduce the material goods and/or services that come into the work area of the university. Managers need to develop systems and structures within their organisations that satisfy the requirements of green business practices while still achieving strategic business goals. Computing is definitely both part of the problem and the solution. Aiming to develop green IT practices in universities requires a careful assessment of what green services offer and the products they use. Figure 2-6 portrays green IT practices on the usage and operations of products and services.
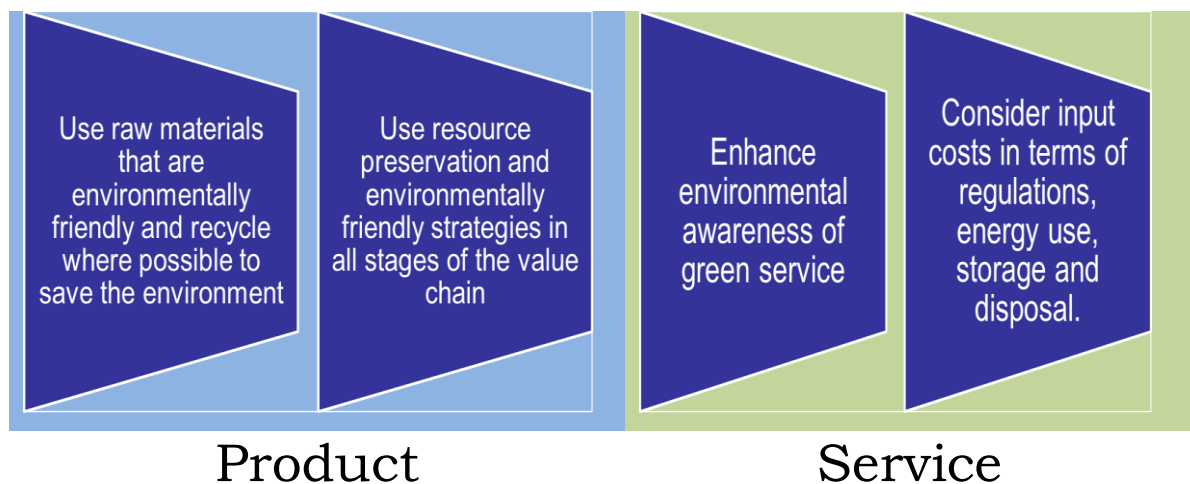
Product   **Service**

Figure 2-6: A framework aiming to develop green IT practices on products and services' usage and operations

2.11 Research questions

1. What approaches can be implemented in a university that currently owns huge number of computers, other electronic products and IT infrastructures as IT hardware poses severe environmental problems both during its production and disposal, as new products are purchased, obsolete products are stored or discarded to make IT environmentally friendly and secure the implementation of strategies in relation to e-waste disposal?

2. What measures should be implemented to reduce the generation of greenhouse gas (GHG) emission, pollution of carbon footprint and energy consumption and other related side-effects throughout the upstream and downstream processes associated with the production and operation, including the redesign of alternative solutions?

3. What is the key environmental impact arising from IT equipment use and what are the major issues that have to be addressed to reduce IT's environmental problems and create a sustainable environment?

4. How will IT affect the start-up cost in implementing rapid technology changes that offer considerably under-powered (energy-saving) benefits for adopting green IT products, applications, services, policies and practices?

2.12 Chapter summary

The literature review broadly discussed contemporary concepts of green IT practices to demonstrate the way in which the thesis builds upon recent research for measuring sustainable green IT practices in universities of South Africa. The scientific method is constantly applied to research, building on previous studies to add new knowledge and discoveries to the incredible size and diversity of scientific fields. Although there is undoubtedly extracts from different studies and articles, the literature study offers value to academics by way of an applied systematic literature review process.

This process includes a systematic literature search strategy resulting in a rigorous literature review that forms the theoretical foundation of the study. In addition, the study addresses an important research gap, and makes an original and valuable contributions to the academic body of knowledge by way of explicating the enabling and transforming capabilities of measuring sustainable green IT practices for environmental sustainability in general, and education in particular.

Current literature indicates that information on green IT research on educational basis of environmental sustainability is scarce. The research addresses this gap and contributes to the value of sustainable green IT practices in the vital domain of environmental sustainability. A framework for measuring sustainable green IT practices provides education with an effective approach to environmental stewardship. This study probes the importance of a comprehensive approach to sustainability implementation and the careful use of administrative power to effectively reach goals.

Although technology may cause many problems, the benefits of technology, undoubtedly overcome its drawbacks. There are real problems that can occur due to the technological revolution, but these problems are in most cases manageable by using more ways and practices of advanced and renovated technologies. In any case, the literature review sets out the intensions of the research concepts to support the claim of a rigorous literature review in providing a focus for the results; moreover it unveiled an investigation and means of tools based on different critical reviews for the evaluation and judgement of its worth.

The next chapter provides the research methodology. It begins with the determination of the high-level research strategy, including the ontological and epistemological assumptions that underpin the research and determine the lower levels of the research methodology.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The previous chapter provided a systematic literature review to assess earlier studies in line with contemporary data in order to pose a question or proposition for current research. It presented an overview examination to guide the theoretical foundation for the study, based on a selection of certain keywords from the problem statement to design a sound methodology for the chosen problem as well as to understand the essential research methods of what is studied and how it is studied. This chapter (Chapter 3) presents the research process in addressing the research problem (section 1.4), achieving the research objective (section 1.5) and answering the research questions (section 2.11) to establish the components of the concept of sustainable green IT practices.

The purpose of the research design and methodology is to determine responses to questions through the application of scientific measures. The prime objective of this research is to discover the content of knowledge required for sustainable green IT practice, and measures to expose the philosophical concepts that support the research approach and define the lower levels of the research methodology and to clarify the subsequent research methods, especially the aspects of processing of data sampling, data-collection instruments and data analysis.

This chapter comprehensively focuses on describing types of research designs, the use of the qualitative method and its underlying philosophical assumptions about discovering and understanding the experiences, perspectives, and thoughts of participants. In addition, it explains the criteria used to select research methodologies, strategies, approaches, data-collection instruments and the analytical objectives. In order to ensure the trustworthiness of the research, the study eventually addresses the ethical issues considered in this research and the method used to validate are explained.

3.2 Types of research and methodology used

Research methodology refers to the steps or approaches taken to link the research question and objectives to data collection, analysis and interpretation in a logical manner (Hartley,

2004; Yin, 2003). Research is based on some fundamental and philosophical assumptions about what constitutes proper research and which research methods are applicable for the development of knowledge in a given study (Oates, 2008). There are a number of methods and designs to obtain scientific information. According to Gill and Johnson (2010), there is no way of identifying a research method as universally applicable.

The most common types of research as described by Neville (2007) are: exploratory, descriptive, analytical, applied, fundamental (basic or pure) and predictive. However, the researcher disregarded all types of research and focused only on the exploratory research. Since green IT is a new topic and no substantial studies have been done on it, it turns to fall under the exploratory research type. Exploratory research is undertaken when few or no previous studies have been done. The objective is to look for designs, hypotheses or concepts that can be tested and can form the basis for further research (Neville, 2007); and to address the high level of uncertainty and ignorance about the subject if the problem is not very well understood (Creswell, 2009) or where there is very little existence of research on the subject matter.

The descriptive type of research is not used in this study, since it is an explanation of the nature of certain situations, relations, systems and people (Leedy & Ormrod, 2005) yet there is no control of the variables. In descriptive research the researcher can only report what has happened or what is happening. In other words, there is no need of manipulating variables, as the purpose is to obtain data about the link between the causes and results. Descriptive research cannot be used to construct a fundamental relationship, where one variable affects another (Portney & Watkins, 2000). On the other hand, in analytical research, the researcher has to use facts or information already available and analyse these to make a critical evaluation of the material. The same method of avoidance can also be applied to the other types of researches such as applied versus fundamental. Applied research aims at finding the solution for an immediate problem facing a society or an organisation, while fundamental research provides generally applicable insights. Hence, these types of research may regrettably not lead to immediate use or application. The researcher in this study selected the exploratory type in order to discover ideas and insights as opposed to collecting statistical data.

Research design deals with the overall plan of the research and articulates what data are required (primary or secondary, qualitative or quantitative or a combination), what methods are being planned to collect and analyse this data, how all of this is going to

answer the research question and what techniques are used in reporting and analysing the findings of data. It is about designing the overall structure of the research (Bless *et al.,* 2006). Exploratory research design is an appropriate and supreme design for this research to identify a problem, explain the nature and define the scope of it, to uncover new knowledge in a field where very little is known, develop propositions and hypotheses for further research, and to reach a greater understanding of an issue (Creswell, 2009).

Figure 3-1 shows the overview of the research process from the philosophical grounding to data acquisition.
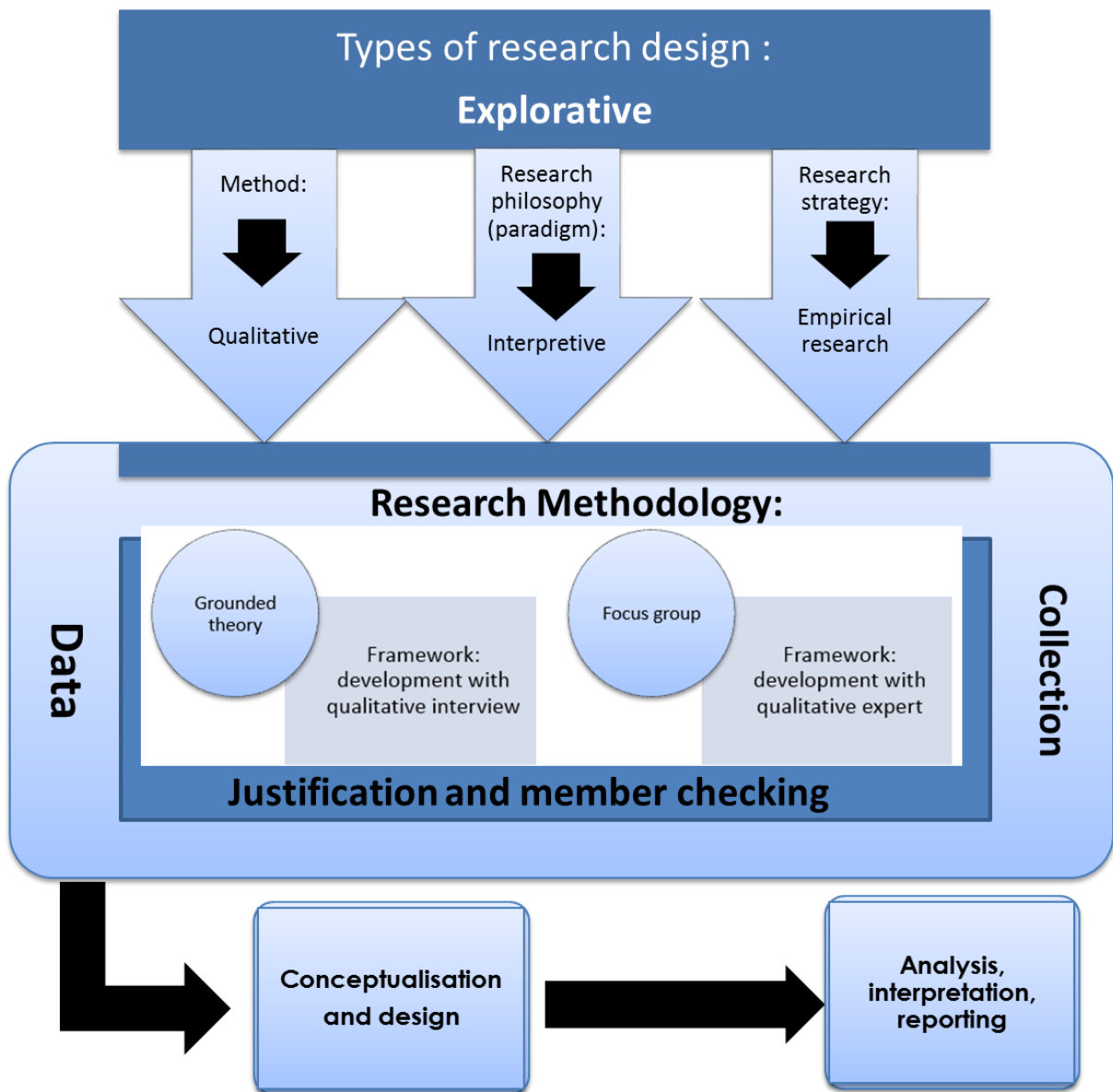
Figure 3-1: High-level research design

This study follows an empirical path that comprises collecting primary data in the field. The empirical path is required for the researcher to achieve the research objective. In addition, the high-level research strategy involves the philosophical grounding of the paradigm's assumptions that underpin the research which determine the lower-level implementations of the research methodology. The above-mentioned interpretive nature of qualitative research in line with the fundamental purpose of the exploratory method is considered as suitable for this research process.

The qualitative research method is chosen to gather data from interviews rather than a quantitative or triangulation method. Qualitative research is concerned with the phenomenon involving quality analysis. It helps to gather information concerning the experience of individuals or groups of individuals on a phenomenon. Its prime objective is to obtain the meaning and emotion and express the situation (Supino & Borer, 2012). The why and how involved in making decisions can be investigated with qualitative research methods. Qualitative analysis involves reasoning and textual rather than graphical representation. Most of the time, qualitative analysis is used for descriptive, explanatory or exploratory researches (Portney & Watkins, 2000). Therefore it properly suits the researcher's choice for an exploratory type of research.

3.3 Philosophical grounding of paradigm in research

A research procedure is a step-by-step method of conducting a research study. It begins with a research philosophy. The term philosophy is taken from the ancient Greek combination of two words, "philo = φιλο" meaning "love" and "sophia = σοφία" meaning "wisdom". (Wikipedia, n.d.) Thus, all together the "philosophy" connotes "the love of wisdom". Yet, in modern time, philosophy is a controversial subject which deals with the most fundamental aspects of reality and value of what to research, how to research and the reason why the research is conducted (Burrell & Morgan, 1979), rather than "the love of wisdom". As suggested by Dobson (2002), understanding different philosophical arguments benefit researcher to discuss different paradigms that encourage researchers to study phenomena in different and coherent ways. Denzin and Lincoln (2008) also highlight how different kinds of knowledge may be derived through observing the same phenomena from different philosophical perspectives.

In times, some researchers have categorised philosophical groundings as being three, namely ontology, epistemology and methodology (Burrell & Morgan, 1979; Dash, 2005), and others as four, namely ontology, epistemology, methodology and axiology (Mertens, 1998; Mertens & McLaughlin, 2004). Likewise, some researchers also have different ways of classifying research paradigms, as being three namely, positivism, interpretivism and critical theory/emancipatory; and others as four or more by adding to them community of practice, reflexivity and so on, to confront the research in their attempt to evaluate and qualify the fidelity of the research process (Myers & Newman, 2007). In addition to that, different terms are often used to describe similar paradigms; as a result of this, similar approaches are developed in parallel across different branches of the social sciences (Denzin & Lincoln, 2008).

Common philosophical assumptions were reviewed and presented. The main philosophical groundings and research paradigms discussed in this study, adopted from Mertens (1998), and Mertens and McLaughlin (2004), as outlined in the Table 3-1 below are: 1) Ontology: the study that describes the nature of reality (what is real and what is not, what is fundamental and what is derivative), 2) epistemology: the study that explores the nature of knowledge (how can we be certain of what we know or based on what does knowledge depend), 3) methodology: the study of approaches to systematic enquiry for conducting research (how is the research carried out) and 4) axiology: the study of value (what value does an individual hold and why). This perspective is based on the researcher's assumptions concerning the interrelated concepts of ontology, epistemology, methodology and axiology.

Table 3.1 below, demonstrates the difference between and relationship of the research paradigms along with the philosophical groundings.

	Positivism/Post-positivism	Constructivism /interpretivism/anti -positivism	Emancipatory / critical social
Ontology (Nature of reality)	▪ One reality ▪ Reality knowable within probability	▪ Multiple socially constructed realities	▪ Multiple realities influenced by society, politics, culture, economy, gender, etc.
Epistemology (Nature of knowledge, relationship between knower and what can be known)	▪ Objectivity is important ▪ One "body of knowledge" ▪ Researcher manipulates and observes in a dispassionate, objective manner	▪ Knowledge is socially constructed ▪ Framework/values are made explicit ▪ Interactive link between researcher and participants/context	▪ Knowledge is socially, historically, culturally situated ▪ Interactive/activist link between researcher and participants/context
Methodology (Approach to systematic inquiry)	▪ Quantitative ▪ Interventionist ▪ Decontextualized	▪ Qualitative ▪ Hermeneutical ▪ Dialectical ▪ Contextual features important	▪ Qualitative (primarily) ▪ Quantitative (can be applied) ▪ Contextual/historical features important as they relate to oppression
Methodology (Purpose for conducting research)	▪ Predict ▪ Test ▪ Measure ▪ Prove ▪ Disprove	▪ Understand ▪ Construct meaning from participants' perspectives	▪ Promote social change ▪ Liberate ▪ Emancipate ▪ Critique ▪ Take political action
Axiology (Value and judgment)	▪ Value free/theoretically influenced ▪ Suspend judgment until statistical tests prove/disprove	▪ Judgment is based upon consensus of participants and researcher ▪ Varies upon theoretical framework/values held by researcher	▪ Judgment is the experienced oppression by participants or "beliefs in action" of participants ▪ Framed by beliefs/values of all participants

Table 3-1: Research paradigm along with the philosophical grounding, adopted from Mortens (1998) and Mertens & McLaughlin (2004)

3.4 Research paradigm

A "paradigm" is defined as an ideal or model, within which theories and experiments performed in support of a philosophical and theoretical framework (Merriam-Webster.com., n.d.). Denzin and Lincoln (2008) describe a research paradigm as 'an interpretive framework' and Guba (1990), as a 'basic set of beliefs that guides action'. According to Kuhn (1970) paradigm refers to a research culture with a set of beliefs, value and assumptions of the aspect of realities. When undertaking scientific research, it is important to consider the different research paradigms. The most commonly applied research paradigms are positivist, interpretivist and critical theory. Each of these paradigm methods are used in carrying out this scientific investigations.

A positivist research paradigm emphasizes an objectivist approach to studying social phenomena and gives importance to research methods focusing on quantitative analysis, surveys and experiments (Mertens & McLaughlin, 2004). An interpretivism or anti-positivist research paradigm stresses on a subjectivist approach to studying social phenomena and attaches importance to a range of research techniques focusing on qualitative analysis (Mertens, 1998). The third research pradigm, critical theory, suggests ideology critique and action research as research methods to explore the existing phenomena. Interpretive research gives greater scope to address issues of influence and impact and to analysis questions such as "why" and "how" of particular technological streams (Deetz, 1996)

Positivism is grounded upon values of reason, truth and validity and focuses that attention purely on facts gathered through direct observation and experience and measured empirically using quantitative methods (Blaikie, 1993). The researcher is not interested in a positivists paradigm that systematizes the knowledge generation process with the help of quantification to enhance precision in the description of parameters and the discernment of the relationship among the realities. According to the critics of a positive paradigm, objectivity needs to be substituted by subjectivity in the process of scientific inquiry (Dash, 2005). Likewise, since the critical theory concerns how knowledge is acquired and disseminated, the researcher did not support the critical theory paradigm in this study for it did not match in carrying out the intended scientific investigations.

Research differ in approach and in how evaluation is done. Mavetera and Kroeze (2009) remark that different research paradigms have different views of ontology and

epistemology i.e. views about the nature of the world and the ways in which knowledge is acquired. The quality and significance of any research is mainly reflected in the research paradigm used and accepted as appropriate. These is the reason why researchers need to identify the philosophical paradigm behind any research (Guba, 2004).

Research paradigm corresponding methodology looks at the importance of knowing and articulating the philosophical perspective. The research paradigm chosen for this research is an interpretivist paradigm (naturalistic inquiry) and a constructivist paradigm that support multiple socially constructed realities. Besides, grounded theory is predominantly used in interpretive studies because it provided a set of procedures for coding and analysing data which suited the interpretive approach in keeping the analysis close to the data and provide for inductive discoveries about the phenomena under study (Urquhart, 2001). Although grounded theory was originally developed as a research paradigm in post-positivism (Annells, 1996), the researcher located the use of grounded theory within an interpretivist hermeneutic paradigm as a means of underlying philosophical assumptions.

Following the above discussions, this research study has illustrated that grounded theory, as a method associated with the social science perspective, can assist with a rich, context-based interpretive research paradigm. In fact, the most notable grounded theory in Information Systems research conducted by Orlikowski (1993) in the study of the adoption and use of CASE tools presented that grounded theory fitted well with the interpretivist rather than positivist nature of the research. Furthermore, as Urquhart (2001) noted, grounded theory with an interpretivist paradigm has become increasingly common in the IT research, for the method is useful in developing context-based, process-oriented descriptions and explanations of phenomenon.

3.5 Validations of research methods

Basically social studies involve qualitative and quantitative methods. The choice of a research methodology depends upon the research method selected. The method can either be qualitative or quantitative, which is influenced by the research paradigm (positivist, interpretivist or critical social). Neither of these methods is intrinsically better than the other, but qualitative is preferred to quantitative for its ability to interpret phenomena in terms of the rich and ineresting explanations that respondents bring into the research.

Research methods are techniques for collecting and analysing, or ratifying data in scientific or scholarly research (Myers & Newman 2007). These techniques typically

follow a plan, a routine or a scheme. Methods are not a limitation, they allow for creativity and new visualization. Not everything that is thought and every strategy that can be planned out can be put into practice. Methodological competence and design will yield solid work.

3.5.1 Qualitative method

A qualitative method is a type of scientific research that systematically tries to understand a given research problem or perspective of a particular population in obtaining culturally specific information about the value, opinion, behaviours and social context of a particular population. It uses a scientifically predefined set of procedures to answer the question or collect evidence. Qualitative research encompasses a number of research designs, including ethnography, phenomenology, case studies and interview studies (Creswell, 2009; Spradley *et al.,* 1972). One advantage of qualitative methods in exploratory research is the use of open-ended and probing questions giving participants the opportunity to answer in their own words, rather than compelling them to choose from fixed responses, as quantitative methods do.

The qualitative scheme selected for this research is the interview method. The purpose of the qualitative interview method is to capture the world as seen by the participant (Spradley *et al.,* 1972). There are several types of interviews, such as life histories, evaluation interviews and qualitative interviews (Denzin & Lincoln, 2005). Qualitative research methodology aims at discovering the fundamental motives and desires, using in-depth interviews for questions that can be modified to reflect new theory.

Other techniques of research used by qualitative method as defined by Klopper and Lubbe (2011) are, word association tests, sentence completion tests, story completion tests and similar other projective techniques. According to Van Maanen (cited in Ghauri, Gronhaug, & Kristianslund*,* 1995), the skilfulness required to conduct qualitative research is thinking abstractly, stepping back and critically analysing situations, recognizing and avoiding biases, obtaining valid and reliable information, getting theoretical and social sensitivity and the ability to keep logical distance while at the same time utilizing past experience, as well as a smart sense of observation and interaction.

There are three major components of qualitative research mentioned by Strausss and Corbin cited in Ghauri *et al.,* (1995): firstly, the data is often collected through interviews and observation, secondly, the interpretive or analytical procedure conceptualizes and

analyses the data to arrive at finding theories and, finally, the report may be written or verbal. Taking all of the above mentioned concepts into consideration, the researcher uses a triangulation qualitative research method to capture some of the theoretical positions using different angles of information in order to increase the validity of the study, whether the findings of a study are true and certain. "True" in the sense that research findings accurately reflect the situation, and "certain" in the sense that research findings are supported by the substantiation. Triangulation is a method used by qualitative researchers to check and establish validity in their studies by analysing a research question from multiple perspectives (Patton, 2002). In this research the researcher uses the term triangulation method in a way of discovering valid information, but not in the sense of using combined research methodology (qualitative and quantitative).

3.5.2 Quantitative method

In contrast to the qualitative method, the quantitative research concentrates on numerical measurements of scale, range and frequency. It is applicable to phenomena that can be expressed in terms of quantities: such as statistics, mathematics or computed quantities (Hartley, 2004). Qualitative data, on the other hand, are data that rely on observation and interpretation as opposed to numbers, and may be depicted using a variety of media. Quantitative research has to be based on the interpretation of quantification of results (Neville, 2007). Although there are a number of slight differences between the two types of methods, there is one very important distinction. The qualitative aims at discovering the underlying motives and desires, using in-depth interviews that is inductive and does not require a hypothesis in order to start the research process.

Ghauri *et al.* (1995) affirm that the difference between quantitative and qualitative research is not 'quality' but procedure. Denzin and Lincoln (2005) explain qualitative methods as being typically more flexible, allowing greater spontaneity and adaptation of the interaction between the researcher and the study participant. Qualitative methods ask mostly "open-ended" questions that are not necessarily arranged in exactly the same way with each participant. With open-ended questions participants are free to rephrase in their own words, and these responses tend to be more complex than simply "yes" or "no." The key difference between quantitative and qualitative methods is procedure and flexibility. Qualitative methods are typically more flexible instruments and a more flexible iterative style of eliciting and categorizing responses to questions.

Qualitative research methods, as opposed to quantitative methods, are used for an in-depth understanding, for case study and participant observation to unearth underlying motivations and factors that influence decision making and opinions to measure sustainable green IT practices (Creswell, 2009). Although qualitative type of research can be easier to start with it is often difficult to interpret and present the findings; and the findings can also be challenged more easily. However, since, the qualitative method is more subjective in nature, it is preferable and a more meaningful way of conducting a study than quantitative methods.

The reason for using the qualitative method is because it can help to develop propositions for further testing, understand the feelings, values, and perceptions of how respondents perceive the existing real phenomena. Qualitative research generally follows inductive theory building which is a theory developed by interpreting the empirical evidence collected within the study (Denzin & Lincoln, 2005). In addition to that, the researcher intends to study the opinions and views of people and also the social context within which they exist; for qualitative is required to obtain data from people in real-life settings (Creswell, 2009).

3.6 Developing the research question design

Before investigating types of research questions, it is important to know about the role and purpose of research question, what it maintains and what it is not. Interviews generally strive to answer basic questions: who, what, where, when, how and why. However, social studies mostly asks two types of research design questions: these are descriptive (what is going on) and explanatory (why is it going on). Although the researcher concentrates somehow on explanatory to probe exploratory research, opposing to concrete, an abstract descriptive questions is also fundamental to the research and it will add immeasurably to the knowledge of the shape and nature of the questions. Thus, the design of these research questions is based on what, how and why.

Fundamentally, grounded theory, being a logical generation of theory from systematic research, helped to shape interview questions in order to achieve valuable data while avoiding the imposition of preconceived concepts on the data. Viz. a priori assumption (Charmaz, 2006). Developing the research questions for interviews assisted in providing rich data generation by grounding the interview in the interviewee's own experiences. Interview questions can be constructed on thoughts from the literature review, common-

sense knowledge, the researcher's own in-depth knowledge, and the researcher's own experiences (Bakir & Bakir, 2006).

The interview questions were based on initial findings from the pilot study and survey. They have addressed the secondary research question; and covered all the aspects in the sensitising theoretical framework. The initial step in constructing an effective research question is the identification of research problems and research objectives. These have been identified in Chapter 1 (section 1.4) and (section 1.5) respectively.

The questions are formulated according to the information gleaned during the literature review. The interview questions comprised two sections. The first, section A, requested biographical data from the respondents. The second, section B, concentrated on the respondents understanding of 1) the general concept of sustainable green IT and sustainable environmental awareness 2) e-waste and u-waste disposal management, 3) energy efficiency and carbon footprint reduction 4) technology resource optimisation (hardware and software) for eco-friendly use and 5) socio-economic relevance (See appendix 4.2). As described in this Table 3-2 below, the following themes were addressed.

1 Theme	Initial research question	Interview questions
General concepts of sustainable green IT and sustainable environmental awareness	1. What do you know about sustainable green IT and sustainable environment	1.1 When and where have you heard about green IT 1.2 How important is sustainable green IT to you? 1.3 What role of initiative and motivations should universities, government authorities and even individuals play over all green IT strategy to promote sustainable environment? 1.4 How can a university develop sustainable green IT ethics and a national recognition policy and practices to promote green job towards sustainable products and resources?

2 Theme	Initial research question	Interview questions
E-waste and u-waste disposal management	2. What approaches and strategies can be implemented in organisations to reduce, re-use (refurbish or repair) recycle and remanufacture items in order to improve the sustainability of e-waste management system?	2.1 Once the university has received the new computers and other IT related equipment what should the university do with the obsolete computers? 2.2 What do you think should be the criteria of the university for buying eco-friendly range of products that aim at reducing the e-waste generation and conserving resource? 2.3 What are the possible reasons for discarding the old computers and IT equipment at your organisation?

3 Theme	Research question	Interview question
Energy efficiency and carbon footprint reduction	3. What type of measures should be used to reduce the generation of greenhouse gas (GHG) emission, pollution of carbon footprint and energy consumption as well as other related side effects to minimise the use of energy throughout the life cycle, including the redesign of alternative solutions?	**Power assessment**: 3.1.1 How may green IT policy makers play a significant role in helping the university to reduce IT power consumption and advocate the use of green technology in improving energy-efficiency? 3.1.2 What other alternative approaches of improving energy-efficiency techniques (i.e. renewable energy) could universities have to reduce both their operational costs and IT power consumption within their business? **Footprint assessment:** 3.2.1 What measures should IT leaders implement in pursuing green IT resource and systems' operations to reduce a business's total carbon footprint against the intensive carbon emission?

4 Theme	Research question	Interview question
Technology resource optimisation for eco-friendly use	4. What is the key environmental impact arising from IT that has to be addressed and planned to reduce the environmental problems caused by IT and create a sustainable environment in acquisition, utilisation and effectiveness of new technology to regress environmental impact.	4.1. What new green IT resources (hardware) and systems (software) should be used in transforming the current use of IT resources and system operations to make them more efficient? 4.2. What approaches and methods of green IT practices should be adopted and implemented in a university to create dynamic learning experiences and ways to reduce environmental pollution, impact, footprint and degradation?

5 Theme	Research question	Interview question
Socio-economic relevance	4. How will technology affect the start-up cost in implementing rapid green IT change that considerably offer under-powered (energy-saving) benefit for adopting green IT products, applications, services, policies and practices?	5.1 How will this affect the high start-up cost to the universities as the result of rapid technology change designed considerably under-powered for adopting Green IT towards creating a sustainable environment? 5.2 How will green IT improve the environmental management capabilities and streamline business processes to make the university both greener and profitable? 5.3 How can the readiness of green IT at universities be measured and explained? 6.4. Thanks for all that valuable information. Is there anything else you'd like to add about green IT before we close?

Table 3-2: The alignment of the research questions with interview questions

A good research question helps readers to understand the exact subject matter in addressing the extensive question. For instance, suppose the researcher is interested in addressing the issue of green IT procurement and environmental impacts. If the researcher would like to know such concepts from the respondents' point of view, he would not at all ask something completely like "What is the relationship between green procurement and environmental effects?" because this question evolves too broad a meaning. Besides, this question does not plainly define the problems that the researcher is interested in, nor does it place boundaries on the research design. Instead, it could be rephrased as, "How will green procurement contribute to the environmental issues?" This is a more specific question that leads to a good research question design.

3.7 Data acquisition methods

Leedy and Ormrod (2005) refer to primary data as original information (empirical research) that is collected by the researcher specifically for the research study at hand, for example, data obtained through interviews, surveys, experiments and testing, case studies, or other methods. Secondary data, on the other hand, refers to information that has been previously gathered by someone else for some other purpose (medical, political, scientific and literature works) that can be re-used by the researcher (Denzin & Lincoln, 2005). Secondary sources include books, journal articles and reports, among others. They are theories or concepts collected from extensive previous studies published in relevant scientific textbooks, journal articles and the internet (Ghauri *et al.,* 1995).

The data collected for this research study are obtained from both primary and secondary sources. The primary data are gathered from interviews, while secondary data are obtained from published and unpublished sources, journals, books and various helpful Internet publications based on green IT practices. The information that are obtained from secondary data enabled the researcher to develop the topic of the research study and also determine the information that were helpful in gathering the empirical data for this specific research study.

3.7.1 Method of collecting qualitative data

Information is gathered from all sources and interviews; on direct interaction with individuals on a one-to-one basis. Organising data is assessed in ways that make them easier to work with, and making photocopies of all recording forms, audio or video recordings, and any other collected materials, to guard against loss, accidental erasure or

other problems (Creswell, 2009). Transcribing is done in order to better understand interactions among different variables and to ensure an exact word-for-word text version of the contents of audio or video recordings. Transcribing is time-consuming, yet it allows the interview data to be formatted into a usable form, and the process of transcribing lets the researcher hear the data repeatedly as it is being transcribed.

From the data systematically collected, the main points are highlighted with a series of codes, which are extracted from the text. The codes are grouped into comparable concepts in order to make them more viable. From these concepts, categories are designed, which are the core foundation for the creation of framework.

Data collection is an important aspect of any type of research study. However, one of the core problems regarding to secondary data is that they are collected for the study with different objectives and may not totally comprehend the current research focus. Besides, it is the duty of the researcher to ensure that data are accurate. This suggests that inaccuracies cannot be blamed on the secondary source. It is therefore important to check the original sources of data (Ghauri *et al.,* 1995)

According to Oates (2008), a method is the overall approach to answer research questions. Following from the research paradigm and approach chosen for this study, which is interpretive and qualitative in nature respectively, the case study of interview method will be used as the strategy or method in answering the research problems.

3.7.2 Interviews as an instrument of collecting qualitative data

Interviews allow the researcher to collect a broad range of open-ended, qualitative data. They provide information about people's motivations, attitude, feelings and what they remember and recognise (Nicholls, 2009). Although interviews are time-consuming and resource-intensive, they are generally easier for respondents, especially if what are being sought are opinions or impressions. Besides, as opposed to questionnaires and surveys, it works directly with the respondent and allows the opportunity for enquiring follow-up questions.

An interview can either be brief or in-depth; depending on the researcher' format on how to capture the intended outputs. The advantage of the in-depth interview is that it allows a more correct and precise picture of the respondent's position or behaviour. This method of data collection is highly suitable for exploratory and inductive types of study, as it matches very well with the purpose of this study. Nonetheless, the disadvantage is that in-depth

interviews require a skilled and cautious interviewer. For this reason, there are many factors that are require to be considered before undertaking an interview; for instance complex, negative and attitude questions should be avoided. The interviewer takes a complete understanding of the research problem, its determination and what information is being sought. The progress of the interview is decided by the skills of the interviewer when asking questions and probing more with supplementary questions (Nicholls, 2009).

As indicated by Blumberg (2007), three main type of interviews are conducted in qualitative research. The first type is the "structured interview", where a standard format interview is used with an emphasis on fixed format response categories in which all questions are prepared earlier and put in the same order to each interviewee. The second type is unstructured interviews, where the respondent is given full freedom to discuss reactions, behaviour and opinions on particular matters. The third type is "semi-structured interview" where the interviewers are provided valuable information from the context of participants in a pre-determined set of questions.

Understanding the different setting of the format, the researcher used a standardized semi-structured, open-ended interview consisting of the same open-ended questions to all interviewees; this approach facilitated faster interviews that could be more easily analysed and compared unlike fixed or closed-end interview. The guide approach was intended to ensure that the same general areas of information were collected from each interviewee, which provided more focus than with a conversational approach, yet allowed a degree of freedom and adaptability in getting the information (Blumberg, 2007).

In semi-structured interviews all the questions are asked and similar themes and area to be covered are used. However, the interviewer may omit or add to some of these questions or areas, depending on the situation and the flow of the conversation. As stated by Myers and Newman (2007), the emphasis is on how the interviewee frames and understands issues and events, therefore the interview process is flexible. Semi-structured and unstructured interviews differ from structured interview in that they demand greater skill from the interviewer. Likewise, in semi-structured and unstructured interviews sensitive information about a person is frequently obtained.

Campion *et al.* (1994) explain that telephone interviews enable a researcher to gather information rapidly. However; one of the disadvantages of telephone interviews is that a telephone interview needs to be relatively short, otherwise people feel being imposed

upon. For the sake of this bias, the researcher did not use telephonic interviews but rather used it for some personal information contact with the interviewee. Besides, some respondents may not have telephones or even if they have, they might dislike the intrusion of a call to their office. Hence, to prevent this, the researcher used other means of communication as an option (e.g. e-mail)

The participants were questioned using a semi-structured set of questions which had previously been carefully thought out in order to yield the best outcomes for the research. Semi-structured interviews provide the necessary, rich understanding of the problem. As these questions had already been set, all the participants received the same questions in the same order which made the research fair and able to collect quasi quantitative type of data.

The interviewer needs to know the various ways that the results can inadvertently be biased so as to use a pilot interview to provide bias in the study. During the interview, the researcher prepares to address the following concepts as summarised from Silverman (2000), Myers and Newman (2007):

- Before an interview takes place, explain the purpose of the interview and why they are interviewed.
- Address terms of confidentiality as some of the interviewees might not like it; particularly, any preconception or prejudice that might lead them not to report rich, detailed data. Confidentiality breaches via deductive disclosure is a main concern to the researcher in treating their responses.
- Explain the format of the interview and give a clear idea of precisely where and when the interview will take place.
- Indicate an approximate number and range of questions to be asked and notify the duration of each question of the interview by letting them know how long the interview usually takes.
- The researcher would want to intervene in the following situations: If one group member dominates the discussion or if the group strays from discussing the topic in question; to resolve any conflicts that may arise between group members.
- Provide contact information of the interviewer.
- Allow interviewees to clarify any doubts about the interview.
- Request permission to prepare a method for recording data, e.g., take notes.
- Make sure interviewees are representative of the group.

3.8 Data analysis method

Data analysis is the process of transforming raw data into findings, themes, or propositions. It combines inductive category coding with a simultaneous comparison of all social incidents observed (Delley, 1999). Data collection and analysis occur simultaneously in qualitative research; the process is recursive and dynamic, as the researcher continuously develops, refines, and validates emerging codes (Delley, 1999). The analysis of the qualitative data typically follows the path of aggregating it into categories of information and presenting the diversity of ideas gathered during data collection.

data collected through interview were transcribed, then labelled according to their possible relevance to the subject of the study. Data analysed through a constant comparative method involves comparing one segment of data with another to determine similarities and differences (content analysis). Content analysis allows the researcher to assess theoretical concepts to enhance the understanding of the data and makes it possible to extract words into fewer contexts and related categories to the phenomenon being studied (Denscobe, 2003).

Both grounded theory and content analysis were used to analyse and interpret qualitative data. Although grounded theory and qualitative content analysis share common points of views, they differ somewhat. According to Crotty (2003), grounded theory is treated as a research method, while qualitative content analysis is an analytic method. Besides, according to Krippendorff (2004), grounded theory is treated as a theoretical framework and a content analysis as a research method of textual data analysis. Nevertheless, they are both used to analyse textual materials.

The recording of collected primary data is done concurrently with data collection, so that nothing gets lost and memory does not fade. Besides, concurrent data analysis allows the researcher to become theoretically sensitive to the data. Conducted interviews were reviewed, edited and coded, and the data were transferred to be analysed by the so-called software ATLAS.ti 7.

After the data have been analysed fully, the next major step for qualitative research is to compare and contrast the information given and then interpret the data (Fink, 1995). The qualitative data analysis methods used in this research included the technique of the cross

case analysis and content data analysis tools. The complexity of data were presented according to strategies commonly found in quantitative or statistical studies. If it is worthwhile data may be presented in the forms of tables, diagrams, charts and figures.

3.9 Population and sample selection

Sampling is usually necessary to attempt to gather opinions that are likely to be representative of the whole group – it is thus used to draw from the views of larger groups (Carey & Asbury, 2012). As qualitative research data collection methods are time-consuming, data are usually collected from a smaller sample than would be the case for quantitative approach (Myers & Newman, 2007) For the purpose of this research project, the target population were students or academic staff members and students that are involved in sustainable green IT at South African universities and the sample sizes were gathered from the eleven conventional/traditional universities.

The interview agenda contained five classification of questions in the format of a semi-structured interview, involving a representative sample of IT experts, IT executives and green IT policy makers, computer science and IT lectures as well as post-graduate students from both departments who use the system profoundly and were already acquainted with IT terminologies, acronyms and abbreviations across the eleven conventional/traditional South African universities (See. Appendix 4.1). In order to meet the requirement of being unbiased the researcher chose the convenience sampling method to select five conventional/traditional universities that would constitute the proper sample. Out of those five randomly selected universities, four interviewees were requested from each institution to participate in the discussion in order to measure the impact of green practice implementation in the universities. Thus, the total number of interviewees were twenty.

The convenience sampling method was chosen for convenience, accessibility, and to avoid constraints of time and money (Walliman, 2005). To select different participants or interviewees, the simple random sampling was used, particularly to choose interviewees across five different institutions of higher education. In a simple random sampling, each participant has an equal probability or opportunity of inclusion in the sample (Bryman, 2001).

In the choice of sampling unit, from the large group, it is obvious that the number of unit in the sample shoul be limited to certain size; being as large and heterogeneous as possible to get a good map of the population. Therefore, to reduce the sampling variance of the

estimated population, the researcher used the restructured form initiated by the government of South Africa to merge higher education institutions at aiming to make universities stronger and more focused and efficient.

At the beginning of the 3rd millennium, the governance processes of policy in the South African education extensively restructured the Higher Education Institutions to form Merged Higher Education Institutions (Hall & Symes, 2005). This radical restructuring of major merger education was aimed at making universities stronger and more focused and efficient. As a result of this, there are three types of universities which together offer a full range of courses leading to internationally recognised qualifications. After the national plan for higher education institutions, the number of the South African universities was reduced from 36 to 23 through mergers and campus incorporations, involving most institutions. Currently, the new landscape comprises 23 public higher education institutions in South Africa, of which six are comprehensive universities (Nelson Mandela Metropolitan University, UNISA, University of Johannesburg, University of Venda, University of Zululand, Walter Sisulu University), 11 conventional or traditional universities (University of Cape Town, Rhodes University, University of Pretoria, University of the Free State, University of Fort Hare, North-West University, University of KwaZulu-Natal, University of Limpopo, University of the Western Cape, University of Stellenbosch, University of the Witwatersrand) and six universities of technology (Cape Peninsula University of Technology, Central University of Technology, Durban University of Technology, Tshwane University of Technology, Mangosuthu University of Technology, Vaal University of Technology).

Table 3-3 below shows the sample population of the conventional universities selected for this study among the merged higher education institutions.

Logo	Name	Location
	University of Cape Town	Cape Town
	Rhodes University	Grahams Town
	University of Pretoria	Pretoria, Illovo (Johannesburg)
	University of the Free State	Bloemfontein

	University of Fort Hare	Alice, East London
	North-West University	Mafikeng, Mankwe, Potchefstroom, Vanderbijilpark
	University of KwaZulu-Natal	Durban, Pietermaritzburg, Pinetown, Westville
	University of Limpopo	Polokwane, Ga-Rankuwa
	University of the Western Cape	Bellville (Cape Town)
	University of Stellenbosch	Stellenbosch, Saldanha Bay, Bellville
	University of the Witwatersrand	Johannesburg

Table 3-3: *List of conventional universities on the sample population selected*

As stated above, these three types of universities (conventional, comprehensive and universities of technology) together offer a full range of courses, leading to internationally recognised qualifications.

The criteria that the researcher used to choose 'traditional or conventional' universities rather than others were based on the following reasons:

- the majority of the university are categorized in the traditional universities and therefore, from the higher sampling there is a possibility of drawing accurate results and generalisability.

- a lack of funds and time limited conducting of a study among the entire scope of universities that combine academic and vocationally-oriented education.

- the statistics done by International Education Association of South Africa (IEASA, 2007) portray that traditional (conventional) universities offer bachelor degrees and have a strong research capacity and high proportions of post-graduate students compared to the others. Therefore, this implicit reality of strong research capacity and higher proportions of post-graduate students' activities can depict that the traditional universities are more involved in practice and engagement within time-intensiveness and technology use for their research. This draws together and summarise a set of observations that are seen as important for the study.

- the researcher also used as a criterion the top ten universities of South Africa that offer world-class learning experiences. Unfortunately the higher education institution where the researcher is involved with his study, is not listed in top ten ranking, but is only 11th on the list. Hence by conducting a study of this nature, this institution can learn from it, its students can enter the world of vocation, and can benefit from the study by evaluating its performance and challenges. Besides that, it is actually time-consuming and costly. The figure below illustrates the top ten ranking of best South African universities.
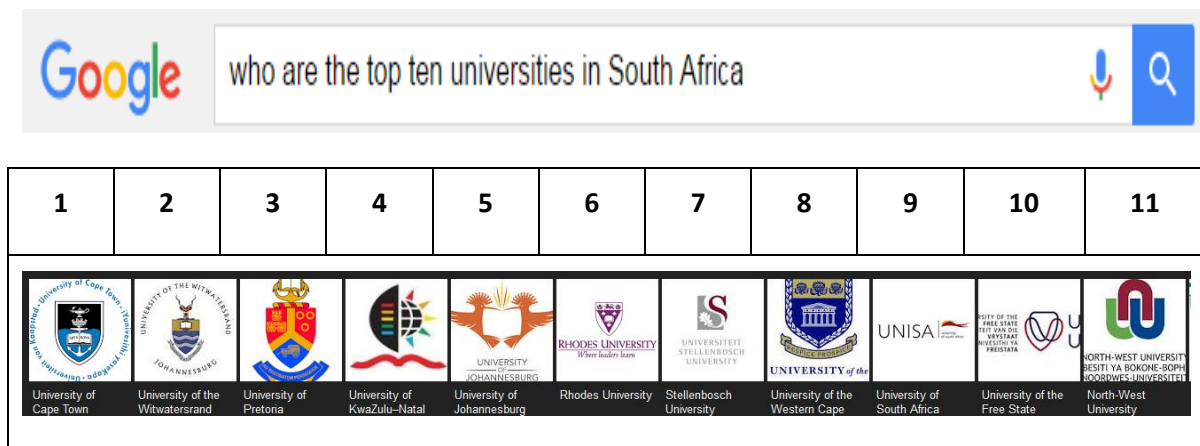
Figure 3-2: The top ten ranking of best South African universities

3.10 Pilot study for interviews

The aim of the research is to measure sustainable green IT practices in universities of South Africa in addressing the issue of energy efficiency, reduction of operating costs or generally minimisation of the negative impact of IT operations on the environment. With the growing body of knowledge and the emergent nature of sustainable green IT concepts, an inductive approach was considered more appropriate (Flick, 2009) Hence, to contribute to the theoretical development empirical data collection was achieved through qualitative interviews. Semi-structured interviews were selected in order to offer same structure for a cross-case comparison (Bryman & Bell, 2011)

'Pre-test' plays a vital role in the development of scientific research. It can be used to determine the feasibility of conducting a large scale study for the variable reproducibility, measurement error, inconsistency and other metrics that can be used to estimate sample size and research methods (Bryman, 2001). As the designed interview questions had never

been disseminated before, in order to evaluate feasibility, time, cost, adverse events, and effect size in an attempt to predict an appropriate sample size and improve upon the study design prior to performance of a full-scale a pilot study was conducted.

As in any research study, it is wise to first pilot the interview procedure on several interviewees prior to data collection. The pre-test interview question was conducted among three interviewees selected by convenience sampling method. Two candidates were selected from the Mafikeng campus of North-West University (NWU) and one from the Westville campus of the University of Kwa-Zulu Natal (UKZN), either involved in some form of green initiatives, or green policy makers or green IT leaders or academic staff lecturers. Some prior problem areas were identified at an early stage and suggestions for improvement were provided, which ensured face validity of the interview.

Based on the initial pre-tests conducted, the pilot review addressed a number of logical issues: 1) repetitive concepts were shortened, 2) questions inclined to quantitative method were eliminated in order to give a valid figure for the interpretations of the results and not for the quantifications. For the sake of scientific proposition some logical improvement were also used to reduce words and phrases using the same terms (redundant) either directly or indirectly. Finally, this paved the road for the researcher to conduct the actual interview questions upon 20 interviewees across five randomly selected universities of South Africa, namely the North-West University (NWU), University of the Witwatersrand (Wits), University of Pretoria (UP), University of KwaZulu-Natal (UKZN) and University of Cape town (UCT).

A pilot study was completed in October and November 2014 to ensure that the data were be free from uncertainty. It was followed by a real study the following year, from February to April 2015, as January was not convenient to the student and academic staff members having to settle from their season holidays.

3.11 Ethical considerations pertaining to the study

It is important for all researchers who conduct research projects to know what constitutes ethical principles and have substantial knowledge about policies and procedures. Not knowing what constitutes ethical research causes irresponsible conduct in research that can make it impossible to achieve a goal (Trochim, 2006). This is actually not considered a viable excuse for ethically questionable projects. Research is a public trust that has to be ethically conducted, reliable and socially responsible if the results ought to be valuable.

The researcher obtained consent from the universities and heads of schools to conduct research in their organisations. Ethical dilemmas raised during this research were taken into consideration throughout this research to develop and define the research problem, purpose(s), questions, data collection, data analysis and interpretation (Hollway & Jefferson, 2000). The researcher followed the existing ethical practices with regard to data collection and the respondents involved throughout this research. One of the most important ethical responsibilities towards the people who were questioned or interviewed was that they were protected from any form of harm when obtaining data (Du Plooy, 2001).

It is important that ethical issues are placed high on the research design agenda for any research endeavour. In exploring the effectiveness of statement analysis, the data collection and its interpretation was conducted and applied in the same ethical manner as cited in Creswell (2009). For this research, ethical practices were considered as important issues in order to avoid harmful effects on the subjects and data sourced from them and other materials (Trochim, 2006). The research followed guidelines of ethical principles to ensure the value of data integrity, impartiality and respect for participants and research communities (Punch, 2000; Creswell, 2009).

The following guidelines were taken in understanding during the research, as detailed by different authors such as (Trochim, 2006), Punch (2000), Denscombe (2003) and Hagan (2000).

- The research was conducted in absolute confidentiality of the identities and the anonymity of the participants protected at all stages of the research as well as in the reports on the final findings.

- Informed consent were addressed and respondents were free to withdraw the consent and discontinue participation in the research interview at any time without prejudice.

- Avoidance of harm such as discomfort, anxiety, harassment, invasion of privacy or dehumanizing procedures during interviews were respected.

- Honesty about information from participants was treated with care and used in such a way as to be secure and to ensure anonymity and ethical responsibility.

- Sympathy was provided where necessary.

- Respect for persons involved and a fair explanation of the purpose of the research, its possible dangers and the credentials of the researcher were shown. The interests of participants were also safeguarded.

- Voluntary participation were encouraged and participants were not coerced in any way to take part in this research.

- For the purpose of this study, the ethical Code of Conduct of the Faculty of Commerce and Administration Research Council were adhered to.

- University research ethics code (Universities Ethical Clearance Code) were complied with in this research. (See. Appendix 4).

After taking the above reasoning into consideration, it becomes evident that the researcher should employ values that should have a meaningful link with the research interview question and with data analysis, in order to direct the researcher to create valid arguments, findings and reports (Leedy & Ormrod, 2005)

3.12 Limitations in conducting interview

The followings were limitations to this study

- The study might convey a most serious limitation resulting from the researcher's lack of access to the participants. Besides, green IT being new feature of the study, as a subject of field, it is not widely known and participants who are involved in the study are not easily traceable.
- In-depth interviews are time consuming and expensive compared to other data collection methods, especially good interviews are hard to write and they take a considerable time to develop and process.
- Interviews may seem intrusive to the respondents and they are also susceptible to interview bias.

3.13 Chapter summary

This chapter explained the several stages involved in the design and development processes, such as the research paradigm, research methodologies, strategies and several designs used in the study, including procedures, participants, data-collection tools and analysis methods, and data credibility issues. Some major philosophical assumptions were reviewed and presented; the interpretive paradigm was identified for the framework of the

study. The research design for this study was highlighted as exploratory and interpretive case study that was analysed largely through qualitative methods. The qualitative research was concerned with the phenomenon involving qualitative analysis to relate the subject with as much openness and inquisitiveness as possible without formulating generalisations in the field of study. The qualitative research helped to gather information concerning the experience of individuals or groups of individuals on a phenomenon. The pilot study was also discussed as a measure of testing the validity and reliability of the research instruments.

The chapter accomplished its objectives by establishing the philosophical concepts underpinning the study; validating the research approach indicated in the research problem, research objective, research questions and clarifying the subsequent research methods, particularly the aspects of the research process, sampling, data collection and data analysis.

Following this chapter, the next chapter (Chapter 4) particularly presents the data obtained from the qualitative grounded theory method. Some other techniques, such as content analysis, correspondence analysis, the qualitative focus group method and qualitative member checking of the actual data-generation process, with reference to the grounded theory will be exposed.

CHAPTER 4

PRESENTATION OF THE GROUNDED THEORY DATA

4.1 Introduction

Grounded theory is one of the most common research designs with the qualitative method. It supports the generation of theory from data, as opposed to testing existing theory. In grounded theory the researcher uses various philosophical and methodological circumstances that influence the implementation of a set of essential grounded-theory methods.

The aim of this chapter is to construct a list of relevant topics that had arisen from the literature review in Chapter 2 and were justified in Chapter 3, which are considered essential to this subject under investigation. The data generated from the literature review are analysed to expose the implemented grounded theory as a competent base for the framework development of green IT practices across the universities of South Africa.

This chapter presents a detailed explanation and description of the grounded theory sampling procedure and data-collection process used for this study. Subsequently, this chapter exposes the data analysis through the focused codes that develop the categories and category properties by explicating the analysis approach for the empirical data.

4.2 Grounded theory research

The grounded theory method (GTM) was introduced and developed by two American researchers, Barney Glaser and Anselm Strauss in their 1967 book titled: *The discovery of grounded theory* (Glaser & Strauss, 1967) in the field of the social sciences and particularly in the field of sociology, with the aim of generating empirically grounded theory shaped by the desire to discover social and psychological process. However, the grounded theory is not constrained to these two disciplines of study. In fact, Gibbs (2010) designates the process of grounded theory can be and has been adopted in many fields of research and different disciplines, such as medicine, law and economics, to mention a few (Gibbs, 2010; Markus, 2007).

Most research methods initiate with theory and then continue by proving the theory. Grounded theory, by contrast, commences by observing the field of the study and then allowing the theory to arise from what is observed, i.e. theoretical formulation or theory

generation. It is a theory that is systematically and inductively arrived at through on-going data collection and analysis for conducting qualitative research intended toward theory development (Bakir & Bakir, 2006). The term grounded theory refers to a method consisting of flexible methodological approaches and the products of this type of inquiry for collecting and, in particular, analysing data. The methodological approaches of the grounded theory are aimed to construct middle-level theories directly from data analysis (Charmaz, 2006).

The grounded theory method is an applicable approach to analysis through systematic methodology involving the discovery of data scientifically obtained and analysed in social science (Bakir and Bakir, 2006). It has considerable significance because it (a) provides explicit, sequential guidelines for conducting qualitative research; (b) offers specific strategies for handling the analytic phases of inquiry; (c) streamlines and integrates data collection and analysis; (d) advances conceptual analysis of qualitative data; and (e) legitimizes qualitative research as scientific inquiry. Grounded theory methods have earned their place as a standard social research method and have influenced researchers from varied disciplines and professions (Charmaz, 2006).

Currently, many strands of grounded theories are in use. All of which are derivatives of the grand grounded theory method (GTM) proposed by Glaser and Strauss (1967), starting with the dicta proposed by these two authors in 1967 on the use of GTM. Although they are several standards, each grounded theory method advocates generating new theory consisting of interrelated concepts rather than testing current theories.

In different research contexts, researchers are encouraged to tune and apply the dicta flexibly for requirements for sound application of GTM. However, it is commanding for researchers to consult the dicta proposed by Glaser and Strauss and to compare these with the GTM variants as proposed by Strauss and Corbin (1998), Glaser (1992), Charmaz (2006), Mavetera (2011) and many other researchers before embarking on any practical research project. This research study uses one variant of GTM and follows a pragmatic-concept approach in the investigation of several issues that are known but not addressed by the current study.

4.2.1 Problem statement and use of research question

Research methodology calls for research generating ideas (hypothesis, problem statement or proposition) and guides the method of data collection and identifies the unit of analysis.

In contrast, using the GTM approach does not need initial generation of a problem statement but, with an interest in the field, i.e. a collection of data by theoretical sampling and analysis of data through the constant comparison method (Mavetera, 2011). Charmaz (2006) suggests, in contrast to Glasser and Strauss (1967) and Glaser (1992), that researchers start with a preliminary literature review that helps to formulate a preliminary theory, research question or hypothesis. In spite of all these scholarly debates, in practice, researchers have to explore through all of these necessities and come up with a research design that is applicable.

4.2.2 Data collection in grounded theory

As it has been explained in the above statement (4.2.1) that the grounded theory does not need an initial generation of the problem statement, it also does not advocate any specific data-collection technique or method (Glaser & Strauss, 1967). The data-collection technique for the grounded theory method of this study entails semi-structured interviews. Interviews are a well-established and useful means of qualitative data collection in interpretive grounded theory, and IS research (Charmaz, 2006; Bakir & Bakir, 2006). The researcher will also use direct observation, document reviews and group discussions to gather data from different angles of sources.

The grounded theory method recognizes two types of codes, namely, substantive and theoretical codes. The conceptual meanings that are specified by the generation of categories and their properties comprise their substantive codes. The ability to generate these codes is of the utmost importance during the generation of grounded theory. To achieve data collection and analysis, three basic coding types are used: 1) open coding, also known as line-by-line coding in order to develop categories of information; 2) axial coding to find link between the categories and 3) selective coding, also known as focused coding, to find the core category throughout the research study (Glaser & Strauss, 1967; Strauss & Corbin, 1998; Glaser, 1992; Charmaz, 2006). These types of coding can be done manually or can be assisted by the use of qualitative analysis software.

Grounded theory coding allows rereading the literature before conducting empirical data acquisition. But attention should be taken not to allow the existing theories in the literature review to misrepresent any new theory, which must be grounded in the empirical data and not in the literature (Glaser & Strauss, 1967; Charmaz, 2006; Corbin & Strauss, 2008).

Concepts developed with grounded theory are evolved directly from the data that contradicts the requirement for additional justification and testing (Urquhart *et al.,* 2010).

The majority of time was spent with primary documents (PDs) whether they be text, audio, graphic, or video. However, for the purpose of optimisation and flexibility, computer-aided qualitative data analysis software such as ATLAS.ti 7 is used for qualitative data analysis to organise concepts and great visual results. Because, the use of qualitative data analysis software can facilitate the integration of grounded methodology with other approaches such as discourse analysis.

Data are collected until theoretical saturation is achieved, that is to say till no new or relevant data remains regarding a category, and the relationships between categories are established (Strauss & Corbin, 1998). Figure 4-1: describes the steps of data-collection instruments and the analysis process used in this study.
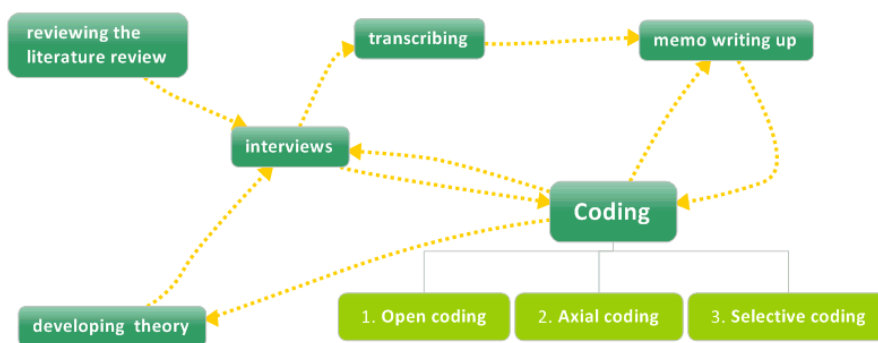
Figure 4-1: *Data collection and analysis process' phases in grounded theory*

4.2.3 Grounded theory data generation and analysis

In grounded theory, a concept develops from the data as it is collected and analysed, the process of analysis takes place from the first time that data are being collected and continues until the research study is completed (Mavetera, 2011). Once satisfactory data have been collected and transcribed, it is possible to progress to the stage that is the building of an indexing (coding) system for the data, following an exploration of all topics that are considered to be important or interesting. These are then labelled according to their possible relevance to the subject of the study. The aim of this step is to build up a list of

relevant topics that come from the interviews and that are considered essential to the subject under investigation.

The generation of theory is a process of converting unprocessed data into information (Charmaz, 2006). In this grounded theory, interview transcripts were coded, interpreted and subjected to several cycles of analysis to come up with the substantive theory. A substantive theory will be developed within the process of categorising differences and similarities of contextualized instances and patterns. The process of data collection for generating theory allows the discovery of theory through the development of categories, category properties, and their commonalities (Glaser & Strauss, 1967; Charmaz, 2006; Corbin & Strauss, 2008).

In grounded theory, initial or open coding was the first stage of data analysis, as it identifies the important words or groups of words. Then the data were labelled accordingly. Usually, verbatim quotes form participants were considered as important words or group of words, while categories were identified as groups of related codes (Mavetera (2011).

To achieve concurrent data generation, the researcher generated some data with an initially purposive theoretical sample. The data from these initial encounters were coded before more data were collected or generated (Glaser & Strauss, 1967). It is vital to lose the prospect of the data; to continuously work with the properties of concepts on data differences and similarities; and to understand what the interviewees are saying about an event instead of the researcher's individual opinions of that event (Corbin & Strauss, 2008).

Writing records (memos) were done to remind the intellectual asset of the researcher during the process of undertaking a grounded theory study. Memoranda (memos) were also used throughout the data analysis process; to record and develop the researcher's analytic insights (Corbin & Strauss, 2008). It is the core of any grounded theory, facilitates discovery, and is the crucial pace between data collection and writing drafts of papers from the very early stages of planning a study until completion (Charmaz, 2006).

The researcher completed the theoretical sampling to focus and feed the constant comparative analysis of the data. During this iterative process, more information was needed to saturate categories under development. This often occurred when the researcher wanted to explore more about the properties of a category, conditions that a particular

category may exist under, the dimensions of a category or the relationship between categories (Strauss & Corbin, 1998).

Grounded theory data analysis provides importance to the data by simplifying the data, understanding it or coding the data, and developing those concepts through elaborated properties (Corbin & Strauss, 2008). Coding is the essential relation between data gathering and the development of an evolving theory; the codes convert the elements of an emergent theory that clarifies the data and guides theoretical sampling (Charmaz, 2006).

The data analysis was directed by the research questions: For instance, "How may green IT policy makers play a significant role in helping the university reduce IT power consumption and advocate the use of sustainable green IT in improving energy efficiency?"

This involves identifying green IT policy makers who play a significant role to assist the universities in reducing their energy consumption and cost reduction and then promote the use of green IT in improving energy-efficiency mechanism. This is done throughout the first level of data analysis. The second step is to identify detailed activities used to implement well-known green practices.

Phase 1: **Recognising a significant role in helping the university to reduce energy consumption and promote sustainable green IT in improving energy efficiency**

The interview transcripts and document collected, need to be reviewed several times to check for relevance and multiple meanings in the statement. The transcripts were read individually and independently of each other. During the process of reading text, the text describing green IT practices in improving energy efficiency will be analysed by using an open-coding technique (Strauss & Corbin, 1998). Here below, Example 1: illustrates how the coding was established, based on the comment from an interview.

Example 1: Example of codes

Example 1 demonstrates the above phrase *"Energy efficiency", "Environmental sustainability", "Equipment or resource reduction" and "Measure green IT readiness",* therefore, following the open-coding technique, they were marked as codes.

Activities identified by interviewees as having an impact on environmental sustainability will be linked to appropriate measures and policy factors by creating relationships between appropriate codes. Relationships identified, are of types starting with "therefore", "leads to" and "in order to". This is illustrated in example 2, which shows how relationships were established.

Example 2: Establishing relationships

Follow the energy star initiatives, advocate the policy of sustainability and implement measures that will reduce the amount of energy used for the activities and even reduce unnecessary resources.

Interpretation:

In order to help university reduce the amount of energy consumption used for the activity (carbon footprint emission) greeen IT policy makers need to follow *"the energy star initiatives"* and advocate *"environmental sustainability"*.

The above statement is interpreted as *"energy efficiency"* Leading to *"following to the energy star initiatives"*. The code *"Equipment or resource reduction"* is linked to the code of *"Measure green IT readiness"*. Codes are also assigned to participants' responses and statements to develop concepts, establishing the beginning of the analytic process.

The final step is to identify main categories from empirical data. This was achieved by grouping codes sharing similar concepts into a sophisticated concepts. This categorisation allows the researcher to remain with fewer elements and enables the main theme to emerge from the data.

After coding numerous interviews a researcher can recognize many issues that are of importance to the respondents. These issues are also known as phenomena and are assigned as conceptual category to become a code, also known as a concept by Strauss and Corbin (1998). Some of these codes or concepts create an interrelationship or similarity characteristics and can be formed together to establish more abstract categories, which can normally be grouped and interlinked to build the basis for a theory.

The following Figure 4-2 represents the process used to associate code with categories:
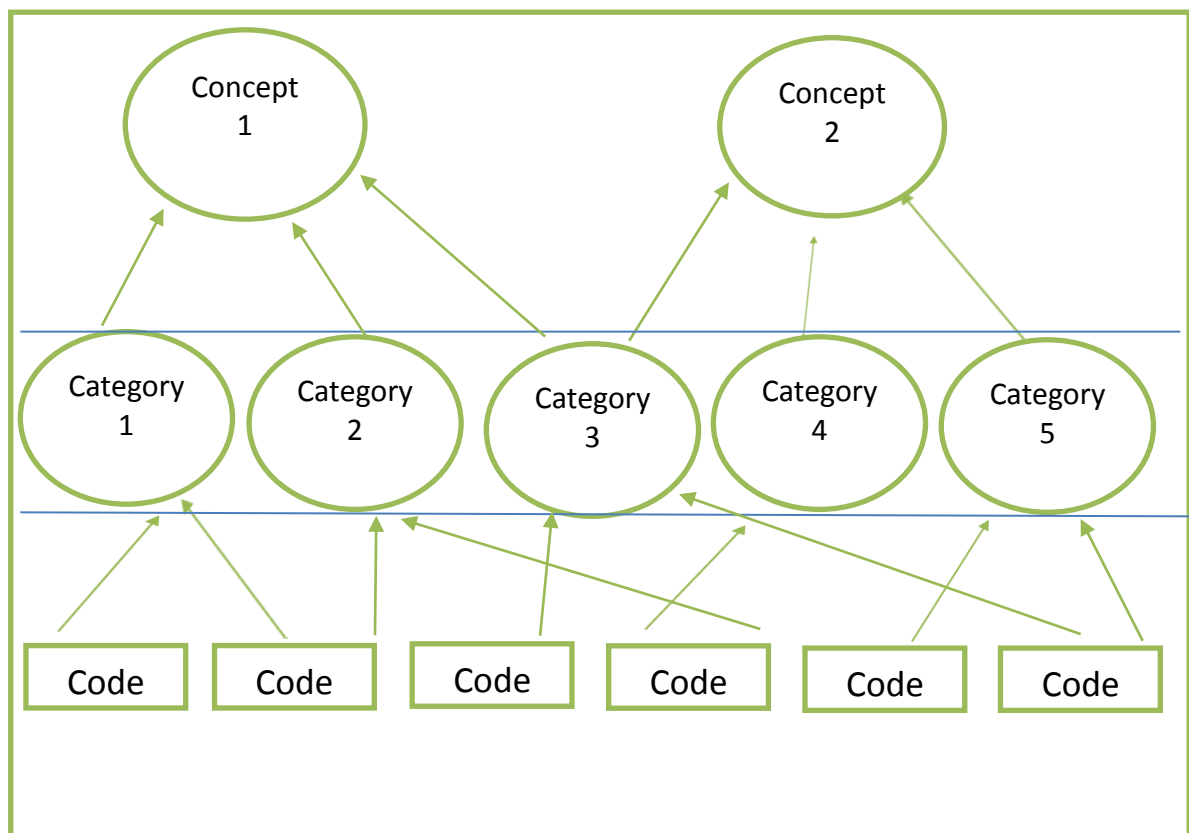
Figure 4-2: *Data link codes' used in primary document to associate code with categories*

Phase 2: **Identification of detailed activities in helping the university to reduce energy consumption and promote sustainable green IT in improving energy efficiency**

At this phase data is examined with the aim to categorise specific activities that enable the implementation of practices in helping the university to reduce energy consumption and natural resource depletion identified in phase 1. Those data were coded. The relationship between specific activities associated with the implementation of practices will be established.

The primary goal of data analysis approaches is constant comparison and questioning. Constant comparison allows the researcher to distinguish concepts and develop their properties and dimensions (Corbin & Strauss, 2008). Therefore, constant comparative analysis using inductive logic were done to compare incident to incident, incident to codes, codes to codes, codes to categories, and categories to categories.

Integration of data is the final phase in analysis. It involves relating categories around core categories and refining the subsequent theoretical construction into a logical, systematic explanatory arrangement (Corbin & Strauss, 2008). Especially, axial coding decides the properties of categories, forms relationships among initial codes, and relates categories to sub-categories (Charmaz, 2006; Corbin & Strauss, 2008).

4.2.4 Focus group

In order to verify the content and correspondence analysis during the grounded theory phase of the research, the study conducted a focus group with green IT experts, specialists and technicians in universities of South Africa. The selective sampling focus group provided decisive evidence from knowledgeable and professional experts in the field of computer for corroboration of the developed framework. The focus group method is consistent with the purpose of interpretivism and is appropriate for IT research (O'hEocha *et al.,* 2012). Hence, the study implemented this method to answer the research question truthfully, even though it required extensive effort, time, and financial cost, in terms of accessing and gaining commitment from experts.

A focus group enables an accepting environment that puts interviewees at ease allowing them to considerately answer questions in their own words and add meaning to their answers. Ideally, the focus group is led by a team consisting of a moderator and assistant

moderator. The moderator facilitates the conversation, and the assistant takes notes and runs the tape recorder.

4.2.5 Limitations of grounded theory

Grounded theory has limitations like any other research methodology. It comes only from the data collected in literature review and from no other source. It is a way of discovering theory that is grounded in the data collected. Bartlett and Payne, in McKenzie, Powell and Usher (1997), and Mavetera (2011) reveal some of the limitations of ground theory as follows:

- It is complex and time-consuming due to the tiresome coding process and memo-writing as part of the analysis.

- It is also difficult to recruit participants depending on the process of interest and time to gather data.

- The study involves a lengthy process of coding by using specialised software to help speed up the analysis of data.

- Grounded theory is used to explain, predict a phenomenon or to constitute a theory and is a very subjective process, which relies greatly on a researcher's abilities.

- It is not developed to test hypotheses and predetermined concepts besides, it is a relatively young and developing method.

Finally, this study followed the methodological guidance of Charmaz (2006) and Strauss and Corbin (1998) to gather and analyse the interview data. Besides, there may be research bias, and a theory created from a small sample of participants might not represent the experience of everyone around the world. Most qualitative researches address "what" and "how" questions; this theory gives the tools to answer the "why" questions as well.

4.3 Categories, category properties and focused codes

Categories are words or phrases that are considered important in creating concepts or phenomena. These initial non-empirical categories are determined by the researcher's general theoretical sensitivity to the research context, which is advocated by grounded theory (Glaser & Strauss, 1967; Charmaz, 2006; Corbin & Strauss, 2008). The categories need not necessarily be the same type, they can be about objects, process and differences. To consider a broader social context, the extended coding process has facilitated

reflections on codes and categories. By bringing several codes together, the categories that are considered essential are highlighted as follows:

4.3.1 Environmental sustainability transformation

Environmental sustainability is the core element that emerged from the data. It has become a great concern to organisations in recent times. The issue of protecting the environment has turned out to be the main focus of the efforts various organizations are making to adhere to an increased degre of environmental responsibility. It has also drawn the attention to scholars, governments and non-governmental agencies, causing them to continuously make efforts towards tackling the problems facing the global environment. Some of the key points identified in this category are the need of in-depth knowledge of sustainability and educational campaign initiatives to continuously make efforts towards tackling the problems facing the global environments.

Sustainable green IT practices for developing and protecting the environment have been adopted with reasonable success in environmental performance. Nevertheless, there are limits to the acquisition of knowledge and practices which are dependent on more comprehensive and actionable in-depth knowledge; therefore a constant awareness and education on environmental sustenance is compulsory.

The need to take action to address this growing list of businesses and environmentally linked issues is driving a wide range of thinking and problem-solving activities. New initiatives are reported from all segments of the industry, including businesses, government, computer manufacturers and service providers. Higher education institutions, on the other hand, offer opportunities to encourage students to take part in eco-friendly activities through environmental associations, clubs, seminars and competition in order to create environmental awareness.

4.3.2 E-waste disposal management

Environmental sustainability helps to establish excellent and functional relationship between knowledge, awareness and action in individuals and organisations. Becoming environmentally responsible may assist individuals to adopt proper e-waste disposal management. The focus of this property is the capability of universities' own internal environmental impact. The focused codes that develop this property are: the issue of

recyclability, acquisition of product quality, compatibility, obsolescence and purchasing of eco-labelled products.

Some of the advantages of e-waste disposal management emerging from the data are: the reduction of greenhouse gas emissions that result from manufacturing and processing events, the avoidance of the unppropriated disposal of toxic e-waste that could lead to air and water contamination enables the prevention of environmental risk. Still, some other importance viewpoints of e-waste disposal managements (re-use, reduce and recycle) are also highlighted as meaningful properties.

The majority of the discarded electronic components comprises of useful materials that can be used for different purposes in future. Thus, reclaiming the resale value is identified as a main issue, as electronic components contain very useful materials that can be re-used even after disassembling. Recycling is considered the best way for conserving existing natural resources (raw materials) by making new products out of recycled materials and save precious resources.

The effect on the environment has to be taken into consideration during the whole life cycle assessment of the product, from the extraction of raw materials to the eventual end of disposing for recyclability, longevity or durability to reduce risk, natural resource depletion, energy consumption, carbon emission and toxicity from hazardous waste and e-waste disposal.

4.3.3 Energy efficiency and conservation

The third property, energy efficiency and conservation, particularly involves three elements: saving energy, improving the use of energy and the reduction of carbon footprints. Rising energy consumption and electricity bills, rising concern over greenhouse gas and hazardous e-waste and the major funds needed to expand the current activity into environmental sustainability transformation are depended on sustainable green IT operations and practices. In order not to be not harmful to the environment, universities need to switch to green IT for cost-effectiveness and a reduction in the use of power and production technology. Energy-efficiency best practices (power management, switch to alternative renewable energy) can also realise significant energy and peak power savings while maintaining or improving reliability, and yield other non-energy benefits.

4.3.4 IT resource optimization for eco-efficiency

The fourth property, IT resource optimisation for eco-efficiency, involves Green IT capability to enable the impartment of an organisation towards creating a sustainable environment. Sustainable green IT optimisation demands products to be manufactured from recyclable materials, efficient, flexible and fanciful in ensuring effective business. Green practice aligned with sustainable green IT features can contribute to business finance and other benefits. Organisational green service must be clearly defined with IT strategies. Material consolidation and quality products are relevant to environmental requirements in shaping the choice of IT products. Therefore, the focus of this property is the design and manufacture of environmentally responsible products in reducing the environmental risk effects through innovation and resource substitution.

4.3.5 Cost analysis benefits

The fifth regulating concept is called cost analysis benefit. The data alludes that environmental sustainability is managed and controlled by measuring its financial or economic value. Sustainability cannot be managed or controlled without optimising performance in the supply chain green procurement, and this has a material effect on any environmental sustainability transformation. This will ensure that the manufacturing process of electronic devices will have little or no negative effect on the environment.

The benefits of some of the lesser-adopted initiatives need to be well understood by respondents. Sustainable green IT measurement is a particularly important initiative, since its data quantify the true cost of energy and products, and allow universities to determine which parts of the IT infrastructure should be optimized next.

The core categories that are considered essential, are highlighted as follows in Figure 4-3 below:
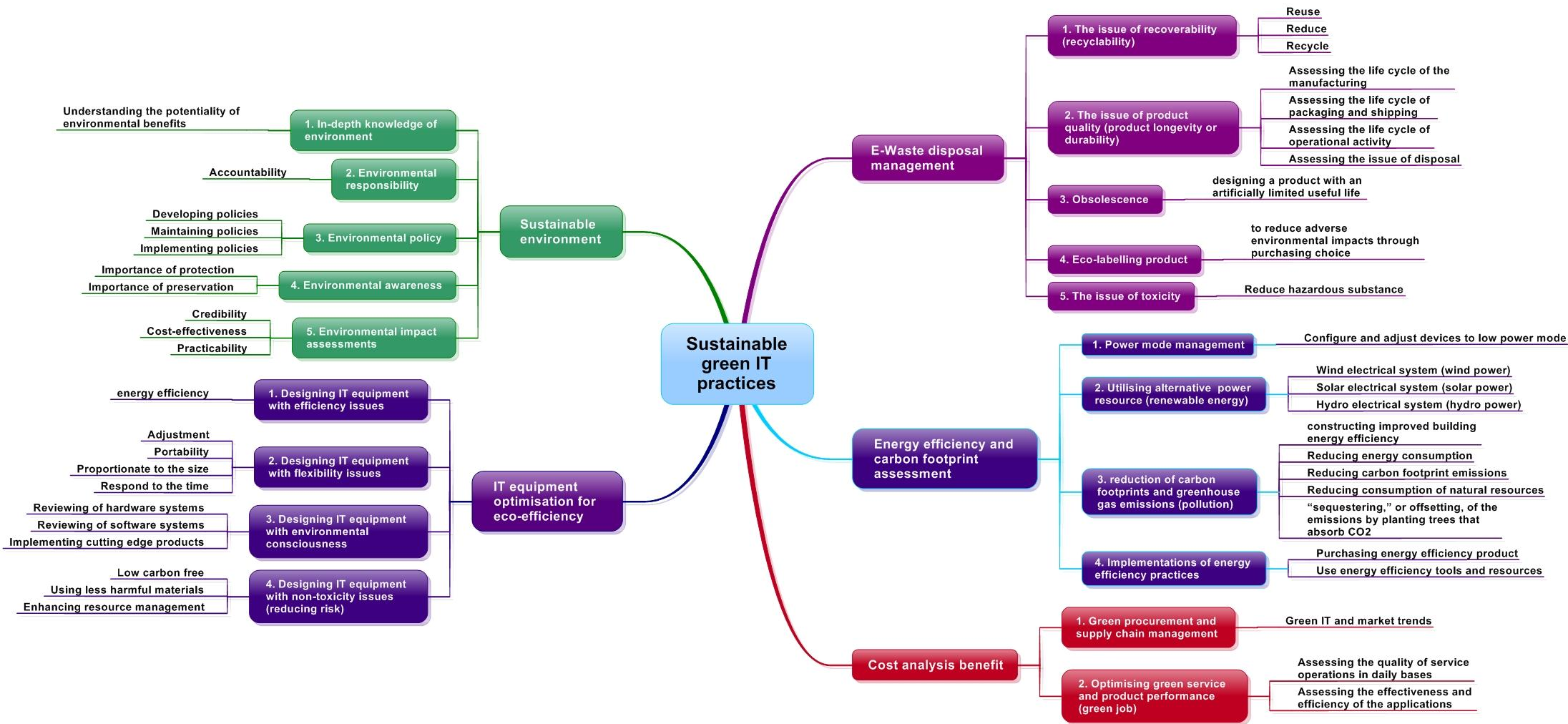
Figure 4-3: *Categories, category properties and focused codes*

4.4 Chapter summary

This chapter explained the choice of grounded theory method research and the relevance to this study. It detailed an outline of the research methodology using grounded theory method that will be applied in the next chapter (Chapter 5). Reasons were provided for the choice of qualitative and interpretive case study simultaneously, and the case selection criteria were also explained.

Chapter 4 discussed a comprehensive account of the grounded theory sampling procedure and data collection process, and the techniques used for data collection and analysis were elaborated upon and explained. Subsequently, the chapter exposed the data analysis through the focused codes that develop the categories and category properties. In the next chapter the finding from all cases are presented.

CHAPTER 5

DATA ANALYSIS AND INTERPRETATION

5.1 Introduction

Chapter 4 focused on the presentation of grounded data theory and its data collection instruments. Interviews were regarded as viable research instruments to collect data at higher educational institutions. IT specialists, Computer Science and IT technicians, Computer Science and IT academic staff members (lectures and post-graduate students) from the universities as well as campus green IT policy makers and green computing initiatives were participants in the interview.

Chapter 5 discusses data analysis and interpretations to conduct the empirical phase of the study. Commencing with the acceptance that knowledge generation using the GTM, necessitates the researcher to have an in-depth knowledge of the incidents and categories of those incidents. This chapter follows on the issues identified in the previous chapter together with the researcher's theoretical sensitivity, as a starting point for the generation of categories of incidents from the interview data that were collected for this research.

The objective of Chapter 5 is to develop proper meaning and interpretation to the collected data. This chapter presents a way of organising meaningful data and explains the content of the concepts that was obtained from the empirical data-gathering. The content may refer to meanings, ideas, messages or themes that can be conversed in detail. In this context, the text whether audio, video, verbal or written is used as means for communication. As a final point, the purpose of this analysis is to discover a framework for measuring green IT practices that can be a guide for use in the universities of South Africa.

5.2 Member checking

As detailed in Chapter 4, respondent validation is considered one of the most important provisions for the credibility of a study and provides validity and applicability of the researcher's emerging theories and inferences (Creswell, 2003). Member checking involves presenting the research findings to key informants to critically analyse the findings and comment whether they are able to recognise their experiences in the findings. Member checking is mainly used in a qualitative method of study and is defined as a

quality control measure by which a researcher pursues to improve the accuracy, validity and credibility of what has been documented during a research interview (Shenton, 2004; Rodon & Pastor, 2007).

5.2.1 Data sampling and collection

The interview part discussed most of the basic content of sustainable green IT practices. It consisted of six separated sections of questions for measuring sustainable green IT and developing a framework that can be used to guide universities in an environmentally sustainable way. The research sample involved 20 respondents or interviewees from five conventional universities. The data of the interviews were first transcribed into documents then imported into a hermeneutic unit (HU) created in ATLAS. ti 7, application software. At this stage, the interviews are known as primary documents (PD).

As grounded theory involves constant comparative analysis, the researcher did not wait until data were fully ready. Instead, the iterative process of concurrent data collection and analysis was completed to assess the systematic choice and study of several comparison groups so that the analysed data guided subsequent data collection (Glaser & Strauss, 1967). GTM is profoundly dependent on the way the data analysis process is prepared. Following the GTM guidance on coding (see section 3.1.1.1), the researcher worked through each of the transcripts and used line-by-line coding to take note of themes and phenomena on the margins. In this case, the first set of interview transcripts that was coded with the help of the qualitative textual analysis for the process of grounding data took place by using ATLAS.ti 7.

The information collected from interviewees need to be organised and readily interpreted. Moreover, the interrelatedness of codes required to be categorised and stored in the same data point (variable). Thus, a qualitative analysis tool, ATLAS.ti 7 assisted the coding process and at a later stage made connections between codes through the creation of "Families". Families are containers or holders for different kinds of objects such as documents, codes and memos.

The data-gathering process provided the primary source of data, which was also complemented by the addition of secondary data obtained from the literature study discussed in Chapter 2. Grounded theory contributed two type of sources, namely substantive and theoretical code that conceptualise categories and their properties as was discussed broadly in section 4.4. Coding procedures in grounded theory approaches were

used to achieve data collection and analysing. In the process of open coding examining, comparing, conceptualizing were applied. Through axial coding, codes were further grouped into families of codes. For instance, a family code that related to equivalent occurrences, such as an environmental sustainability, environmental responsibility, environmental protection and environmental awareness was grouped as one family to sustainable environmental development. Finally, through selective coding the integration of the categories and sub-categories that emerged from the axial coding model have been identified.

5.2.2 Profile of the interviewees

The data-gathering process was aimed at students and academic lecturers in the field of Information Technology and Computer Science departments. A sample size of 20 participants across five universities of South Africa with in-depth knowledge and experience of green IT were purposely prepared for the focus group interviews. Although it is not the major purpose of this study, it is worthwhile explaining the profile of interview respondents.

As tabulated in Table 5-1 below, the twenty participants were targeted from different age groups (the youngest 25 and the oldest 67), as well as gender (male and female) area (North-west University, University of KwaZulu-Natal, University of Pretoria, University of the Witwatersrand and University of Cape Town) with wide-ranging levels of educational and work area background (students, lecturer, administrative officer, network technician, post-doctoral research fellow, graduate assistant, academic development in computer, IT manager and head of division). They were chosen for their ability to provide valuable inputs of sustainable information technology practices that would not negatively impact upon the environment through pollution or depleting natural resources. This sample ensured that the selected participants were representative of the varied population and professional experience, so that findings obtained from such sample provided information which was relevant to the objectives of the study. Besides, it should be noted that interviewees were not discriminatory or differentiating according to gender, proficiency and area of secialisation.

Interviewee	Age	Gender	Occupation	Organisation
P1	67	M	Lecturer since 1971	University of the Witwatersrand
P2	37	F	Administrative Officer	University of the Witwatersrand
P3	N/A	M	Lecturer in IS	North-West University
P4	35	M	PhD student	University of Pretoria
P5	30	M	Lecturer of Computer Science for four years	University of Pretoria
P6	25	M	Academic Assistant for two years	University of the Witwatersrand
P7	38	M	Working for three years as Head of division in IS	University of the Witwatersrand
P8	N/A	F	Working for 15 years and doing post graduate studies	University of Cape Town
P9	42	M	Network technician in computer Science and working for 12 years	University of KwaZulu-Natal
P10	36	M	Working for two years in computer Science department	University of KwaZulu-Natal
P11	31	M	Lecturer, working for two years	North-West University
P12	30	F	Working as academic development in IS & T for five years	University of KwaZulu-Natal
P13	39	M	Working as IT manager for 18 years	University of KwaZulu-Natal
P14	30	N/A	Lecturer for six months	University of Cape Town
P15	31	M	Working as lecturer in Computer Science department since last year	North-West University
P16	36	M	PhD student	University of Pretoria
P17	37	M	Post-doctoral research fellow, system specifications and formal methods	University of Pretoria
P18	45	M	Post-doctoral student	University of Cape Town
P19	36	F	Working as a lecturer less than a year	University of Cape Town
P20	27	M	Master's student and graduate assistant	North-West University

Table 5-1: *Demographic distribution of respondents chosen for their ability to provide inputs for sustainable green IT practices.*

As was indicated in Table 5-1, the interviewees involved in the discussion had a good background of knowledge either in Computer Science, Information Technology or both. Chosen for their ability to provide a wide variety of green IT proficiency helped the researcher to accumulate knowledge from the academic and practical perspective of experience. Academics tend to have a broader and more general knowledge of sustainable educational practices that they may gather from research, reading and teaching students.

The inquiry of sustainable green IT practice interviews took place during June and July 2015. Though it was planned ahead to be conducted specifically in February and March, due to a prolonged process of approval on conducting conferences abroad, this caused a lower response rate than originally planned. Therefore, from July to August, all the interviews were subsequently transcribed by the researcher through the help of the qualitative data analysis and research software named ATLAS.ti 7. The duration from 30 to 35 minutes, within an average duration of 30 minutes in order not to be intended as an exhaustive description/discussion. After each interview was conducted and transcribed, data analysis was followed, using constant comparison in and across the interviews, data, themes, categories, and their interrelationships.

The empirical data acquired from interviewees combined with literature review in the substantive area of study was very important during the initial coding and analysis, eliciting categories and the property of this categories, as well as the disaggregation of core themes (axial coding) as one of data analysis techniques in the process of relating categories to their subcategories.

5.2.3 Thematic evidence of focus group interview

Thematic analysis is a common form of qualitative data analysis in relating two or more subjects that are important to the description of phenomena. As the result of this, the transcripts of the focus group interviews were analysed using a qualitative data analysis programme. The ATLAS.ti 7 application programme tool helped the researcher in identifying data clusters and forming themes and sub-themes of the study. The themes and sub-themes emerged from the interviews involving the five concepts of the study. Previously, the literature review chapter also defined and conceptualised these constructs as research interests focused on sustainable green IT practices and measures.

At an early stage, by using literature reviews and interviews with experts in the field of measuring sustainable green IT practice, 40 codes and six categories were created. Later

on, after using a categorisation chart and tables in order to evaluate the frequency and intensity of these codes, nine numbers of codes were dropped. Only the demographic description code, as it is highlighted in Figure 5-1, was kept back to explain the demographic factors of the twenty focus groups; yet it has nothing to do with themes. Accordingly, the real codes are thirty rather than thirty one.

Code No	Name		Grounded
1	Adoption of telecommuting and video conferencing to reduce travel		5
2	Adoption of virtual classroom		7
3	Alternative way of using energy (Renewable source of energy)		15
4	Clean environment		4
5	Complying with green IT policy		11
6	Considering cloud computing and cluster computing		6
7	Conversion to digital documents		6
8	Cost issues		19
9	Demographic descriptions		20
10	Donation of computer to goodwill		8
11	Energy efficiency		21
12	Environmental awareness and education		14
13	Environmental impact		8
14	Environmental policy		4
15	Environmental protection or preservation		13
16	Environmental responsibility		5
17	Equipment or resource reduction		4
18	Green IT awareness and education		36
19	Green job and service		6
20	Green procurement or purchasing of eco-labelled product		26
21	Hardware and software efficiency design issues		12
22	Hazardous or toxicity of e-Waste		4
23	Implement of BYOD strategy		6
24	Measuring green IT readiness		21
25	Mitigation of carbon footprints		24
26	Obsolescence issues		20
27	Product life cyle assessment		3
28	Quantum computing		1
29	Recyclability issues		29
30	Reduce energy consumption by saving energy		30
31	Residual value		3

Figure 5-1: Code density (grounded): the number of quotations associated with a particular code

In view of that, the analysis of focus group interviews generated five themes and 30 codes in general. Six of the codes described the first theme: sustainable environmental development, while ten of codes described the second theme: IT resource optimization for green solution. Six of the codes described the third theme: e-waste disposal management, four of the codes described the fourth theme, energy efficiency and carbon footprint

reduction, while the fifth and last theme, cost benefit relevance was explained by four number of codes. The visual maps (ATLAS.ti networks) with the themes, subthemes and codes are presented in Figure 5-2.
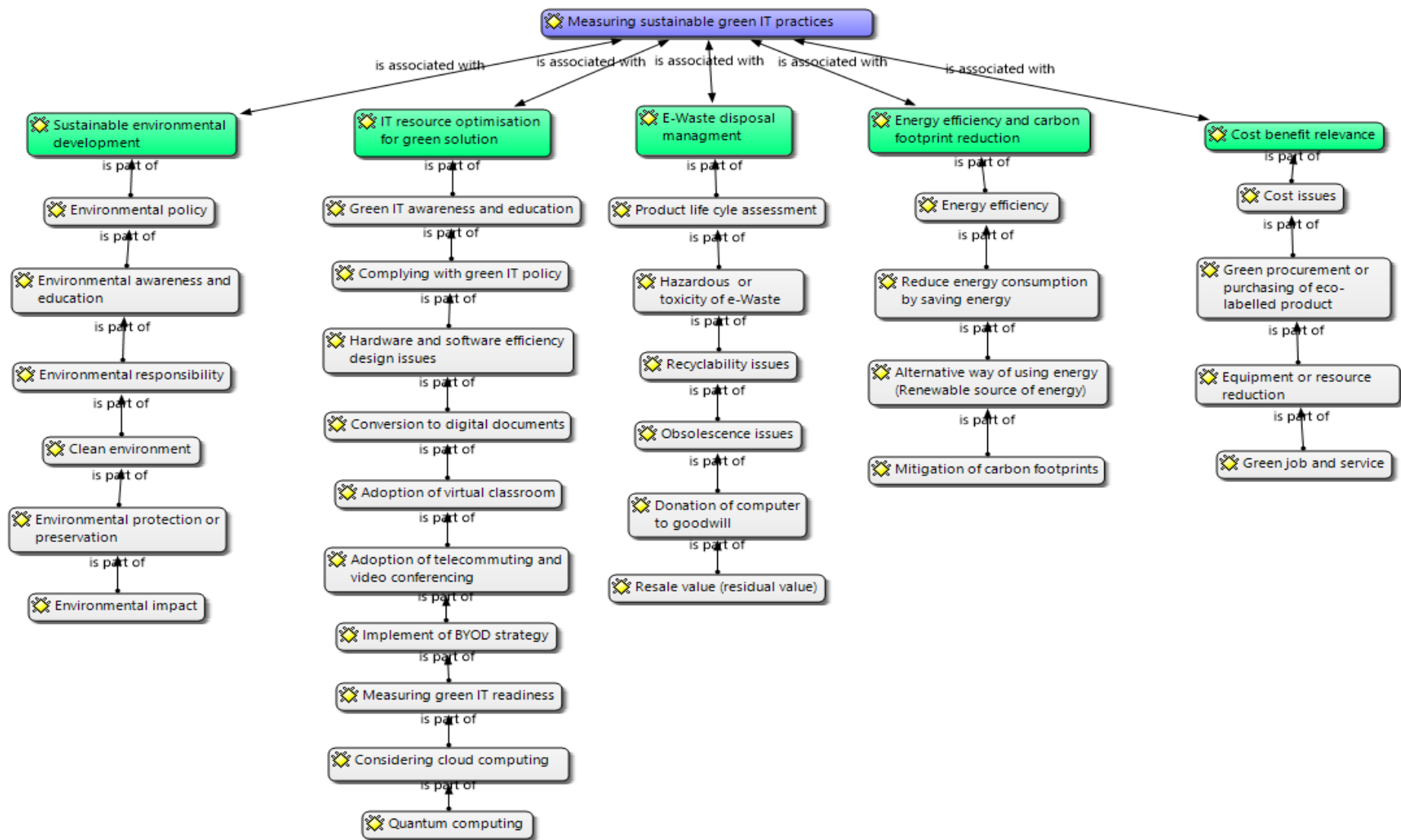
Figure 5-2: *Thematic concepts of themes and sub-themes of focus group for measuring sustainable green IT practice*

5.3 Tabulation score of themes

Content analysis examines the strength of context units contained in the interview transcripts (Krippendorff, 2004). It is a form of textual analysis used to explain and describe characteristics of messages embedded in text. Content analysis can be performed on several types of context units, such as specific words, sentences, characters, or concepts (Oates, 2008).

Grounded theory and content analysis share similarities because they are both intended to analyse and interpret qualitative data. Moreover, they are both used to explore naturalistic inquiries that involve identifying themes and patterns and include rigorous coding. The context unit in this qualitative study is the concept, being the ideas that emerged during the grounded theory analysis (theoretical framework), and in connection with this point, content analysis can be considered a research method of textual data analysis (subjective). Given the strength of grounded theory for emerging theory and its interpretivist philosophy, the grounded theory concepts provide the appropriate points of departure (Bryman & Bell, 2011). It was actually a useful method in allowing the researcher to manage and summarise numerous quantities of information with other research methods.

Table 5-2 illustrates the tabulation scores of the various codes that explained the core of the five themes. Six codes with a total of 48 quotations explained theme 1, sustainable environmental development, and ten codes with 111 quotations theme 2, IT resource optimization for green solution; and six codes with 65 quotations theme 3, e-waste disposal management. Theme 4, energy efficiency and carbon footprint reduction was explained by four codes with a total of 90 quotations, while the last theme 5, cost benefit relevance was explained by four codes having 55 quotations. Overall, 369 meaningful and descriptive quotations, which can be used in generating items for measuring sustainable green IT practices, were obtained from focused group interviews.

Themes	Codes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	Total quotes
1) Sustainable environmental development	Environmental policy		1										1					1		1		4
	Environmental awareness and education	2		1	1		1		1			1			1		2	1		1	2	14
	Environmental responsibility										1		1				1		1		1	5
	Clean environment			1		1				1									1			4
	Environmental protection	2	2		2					1		1							3	1	1	13
	Environmental impacts	1	1	1								1		1		1				2		8
																						48
2) IT resource optimization for green solution	Green IT awareness and education	1	1	3	5	1	3	1	2	1	1	2	1	1	2	1	3	3	1	1	2	36
	Complying with green IT policy	1				1		4	1			1	2		1							11
	Hardware and software efficiency design issues	2	2	1	1						1					3			1	1		12
	Conversion to digital document						1					1	1					1	1	1		6
	Adoption of virtual classroom						1						1	1	2			1	1			7
	Adoption of telecommuting & video conferencing		1		1	1							1	1								5
	Implementing BYOD strategy			1	1								1				1				2	6
	Measuring green IT readiness	1	2		2	1		1	1	1	1	1	2	1		2	2		1		2	21
	Considering cloud computing									1	1				2	1				1		6
	Quantum computing									1												1
																						111
3) e-waste disposal management	Product life cycle assessment														1	1				1		1
	Hazard or toxicity of e-waste			2										1		1						4
	Recyclability issues	1	3	3	2	2	2	4	2	1		2		1	2		1	1		1	1	29
	Obsolescence issues	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
	Donation of computer to goodwill	1						1			1		1		1	1		1	1			8
	Resale value (residual value)	1			1					1												3
																						65
4) Energy efficiency and carbon footprint reduction	Energy efficiency	3			2				3	2				1	2			2	3	2	1	21
	Reduce energy consumption by saving	4	4		2	2	2		1	3	3		1		5	1			1		1	30
	Alternative ways of using energy source		1	2	1	2			1			1	1	2	1		1		1	1		15
	Mitigation of carbon footprint	3	3		1				1		1	1	1	2	2	2	2	3		1	1	24
																						90
5) Cost benefit relevance	Cost issues	1	1	1	2	1			1		1	1	1	3	1	1	1	2	1			19
	Green procurements	2	2	1	1		1	2	1	1	1	3	1	2	1	1	1	1	1	2	1	26
	Equipment or resource reduction					1		1	1			1										4
	Green job and services			1					2	1		1	1									6
	Subtotal for theme 5																					**55**

Table 5-2: Tabulation scores of themes

The content analysis concept contingency table data was key into the statistical software application called Windows Microsoft Office Excel 2013, and graphic statistical analyses were performed. These analyses are based on bar charts showing relative frequencies of each concept, which is a measure of concept importance. Figure 5-3 below, shows the total frequency of each concept across five themes.
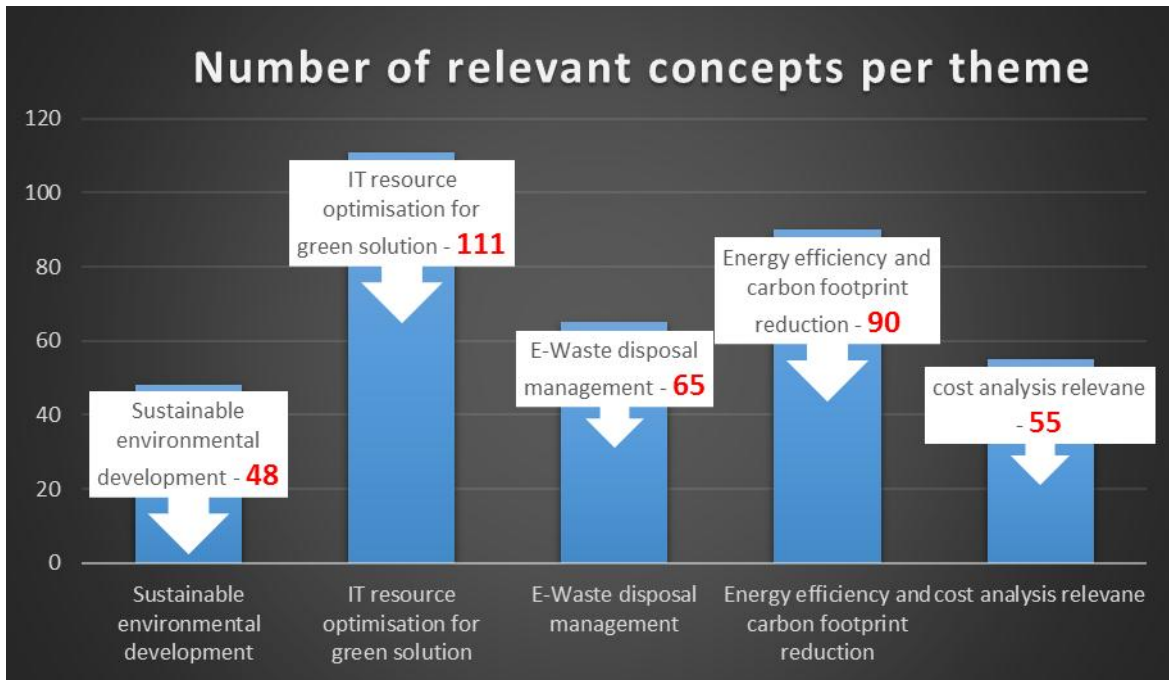
Figure 5-3: *Bar chart showing the total frequency per concept across all codes*

The concepts IT resource optimisation for green solution (111) followed by energy efficiency and carbon footprint reduction (90) are the leading points, having the highest number of quotations associated with themes. Theme 2: IT resource optimisation for green solution, achieved the most scores per code (See Table 5-2). While e-waste disposal management, followed by cost benefit relevance contributed to the third and fourth level of factors respectively. On the other hand, sustainable environmental development contributed the least scores per concept. In this reason, the higher educational institutions need to take their first step to challenge the issue of IT resource optimisation for green solution as well as energy efficiency and carbon footprint reduction as primary factors for an environmentally sustainable plan.

5.4 Research findings

From the focus group responses generated through the interviews, several propositions were formulated for each interview, following the answer required for the study. A summarised presentation of all the interview propositions were then discussed. The propositions presented here are held by a set of propositions from documents with relevant literature on the study. Hence, a justified summary of all propositions as a supportive for the argument from both the interviews and documents was presented to given responses. This proposition will contribute to the study in providing a coherent discourse that will answer the research questions of this study and finally satisfy the aim and objectives of the study. The findings of the focus group interviews were addressed and discussed as follows:

5.4.1 Theme findings towards the green IT framework:

As was stated in Chapter 4, the grounded theory analysis was used, with ATLAS.ti 7 to develop the analysis of the research findings. The grounded theory coding analysis generated expert opinions about both the concepts and their interrelationships. The findings that related to the concepts and their interrelationships, as depicted within the framework, are presented as follows:

Theme 1: Sustainable environmental development

The presentation of the grounded theory data in Chapter 4 is the basis for the development of the attributes of the five themes in this chapter. Following the grounded theory data presentation of the previous chapter, six codes emerged from the first theme of sustainable environmental development, namely 1) environmental policy, 2) environmental awareness and education, 3) environmental responsibility or care, 4) clean environment, 5) environmental protection and 6) environmental impact. These concepts are properties of the core category of sustainable environmental development.

Environmental sustainability encompasses activities to minimise the use of resources, the adoption of recycling programs, the use of renewable rather than non-renewable resources, the redesign of alternative production processes and a reconsideration to mitigate the use of toxic materials, for the benefit of the environment and its community.

Theme 2: IT resource optimisation for a green solution

Green IT is an encompassing field, and progressively important to improve organisational sustainability for promoting ecologically required designs. Following the very first core

theme, sustainable environmental development, a second core theme that emerged from the data was the IT resource optimisation for green solution. It is evident from the data that ten main types of codes for IT resource optimisation are prevalent, namely 1) sustainable green IT awareness and education, 2) compliances with green IT policy, 3) hardware and software efficiency design issues, 4) conversion to digital document, 5) adoption of virtual classroom, 6) adoption of telecommuting & video conferencing to reduce the cost of travel and pollution, 7) implementing BYOD strategy, 8) measuring green IT readiness, 9) consideration about cloud computing, and 10) quantum computing.

IT resource optimization for a green solution referred to as environmental technology or clean technology practice transform and optimize business process and educational collaboration efforts by leveraging opportunities for resource optimization and the reduction of its consumption, in decreasing negative impacts on earth from contaminating the soil, air and water.

Theme 3: E-waste disposal management

The third theme is e-waste disposal management. To face the challenge of e-waste disposal management six codes emerged: 1) product life cycle assessment (LCA), 2) determine the hazard/toxicity of e-waste, 3) develop recycling programme, 4) donate of computer to goodwill, 5) resale value (residual value) to claim the gold, and 6) the case of obsolescence issue, due to the rapid advancement in technology and affinity to newer devices for an expanded demand. E-waste is classified as hazardous waste having adverse health and environmental implications.

Theme 4: Energy efficiency and carbon footprint reduction management

The fourth core theme is energy efficiency and carbon footprint reduction management. This theme, having a component of four codes has the second highest score, following IT resource optimisation for green solution in contributing the most score per concepts. (See Figure 5-3: Bar chart that shows the total frequency per concept across all codes). The four codes that occurred from this theme are: 1) energy efficiency, 2) reduction of energy consumption by saving, 3) alternative ways of using energy source and 4) mitigation of carbon footprints.

When all these codes of the energy efficiency and carbon footprint reduction management are functioning at full capacity it will run smoothly to improve the saving performance, generating maximum financial and environmental returns.

Theme 5: Cost benefit relevance

The fifth core theme is the cost benefit relevance. Four codes emerged from it, namely 1) cost issue for improved access to capital, 2) purchasing eco-labelled products (green procurement) in order to market the IT sector within the organisation to improve or streamline business process, 3) equipment reduction for proper acquisition to increased efficiency and waste reduction and finally 4) an assessment of green job and services review.

5.4.2 Revisiting the research aim and objectives that addressed the framework findings

The research aim and objectives were highlighted once again to give an insight of what the findings of this study addressed. The major objective of the study was to create a framework for measuring green IT practices. For this reason, four main research questions were formulated to answer questions and provide information that satisfied the requirement of the aim and objectives of the research. To give deeper understanding to these research questions minor questions were also derived from them. The questions of the study were broken down as follows:

Theme 1 and Theme 2: Sustainable environmental development and IT resource optimisation for green solution

Main research question 1:

What is the key environmental impact arising from IT equipment use and what are the major issues that have to be addressed to reduce IT's environmental problems and create a sustainable environment?

Minor research questions:

- *When and where have you heard about green IT?*

- *Why is green IT important to you?*

- *What role should universities, government and even individuals' play in green IT strategy?*

- *How can a university develop green policies and practices to promote sustainable products and resources?*

- *What new green IT resources and systems should be used in transforming the current use of IT resources and systems operations to ensure that universities are greener?*

- *What approaches and methods of green IT practices should be adopted and implemented in universities to create a dynamic learning experiences and ways to reduce environmental pollution, impact, carbon footprint and degradation?*

Theme 3: E-waste disposal management

Main research question 2:

What approaches can be implemented in a university that currently owns huge a number of computers, other electronic products and IT infrastructures, as IT hardware poses severe environmental problems both during its production as well as with its disposal; as new products are purchased, obsolete products are stored or discarded to make IT environment-friendly and secure the implementation of strategies in relation to e-waste disposal?

Minor research questions:

- *What should universities do with the obsolete devices once they have received the newer computers/devices?*

- *What should be the scenarios of the universities for buying an eco-friendly range of products that are aimed at reducing e-waste generation and conserving energy and resources?*

- *What are the possible reasons for discarding the old computers or devices at your organisation?*

Theme 4: Energy efficiency and reduction of carbon footprint

Main research question 3:

What measures should be implemented to reduce the generation of greenhouse gas (GHG) emission, pollution of the carbon footprint and energy consumption and other related side-effects throughout the upstream and downstream processes associated with the production and operation, including the redesign of alternative solutions?

Minor research questions:

- *How may green IT policy makers play a significant role in helping the universities to reduce IT power consumption that is aimed at improving energy efficiency?*

- *What other alternative approaches of improving energy-efficiency techniques or means of energy-saving practices could be implemented to reduce energy consumption?*

- *What measures should IT leaders and users implement in pursuing green IT resources and systems operation in universities to make it much greener?*

Theme 5: Cost benefit relevance

Main research question 4:

How will IT affect the start-up cost in implementing rapid technology changes that offer considerably under-powered (energy-saving) benefit for adopting green IT products, applications, services, policies and practices?

Minor research questions:

- *How will the start-up cost affect the university as the result of rapid technology change designed to considerably lower energy consumption and improving efficiency?*

- *How will green IT improve the environmental management capabilities and streamline business processes to make the university both greener and profitable?*

- *How can the readiness of green IT in university be measured and explained?*

5.4.3 Interview responses for each questions

The findings are presented in such way that each result is first discussed individually, after which a graphical or tabulated summary of all interview findings is presented. After discussing the result of the interviews and documents, cross-case analysis was done in order to generate common propositions that would enable universities to cope with sustainable green IT practice.

5.4.3.1 Research question 1

In order to address the two core theme, sustainable environmental development and IT resource optimisation for green solution, six propositions were addressed from the main research question 1:

> **Proposition 1:**
>
> **Raising an awareness on sustainability:** *(When and where did you hear about green IT?)*

According to the interviewees, several have heard about sustainable green IT in seminars, class sessions, surfing on the internet, through mass media, academic exposure, in newspaper, readings, by word of mouth (from friends or colleagues) and side-line conversations. All of these means of communication helped respondents to raise an awareness of sustainable environmental development and sustainable green IT practices.

Green IT being a nascent field of study it was important to understand how the respondents heard about it. This investigation helped researcher to better understand how to target raising an awareness on sustainability. Awareness can be created by displaying green ribbons on websites and wearing T-shirt that display "go green" slogans. Other ways to raise awareness are through sharing information on social medias and blogs, as the web, and specifically social media, has the power to connect student and academic staff members with similar interests. The next important thing about raising awareness for sustainability is to help the universities decide on a best way of raising a significant future awareness.

The respondents who heard about green IT first, did so somewhere around 1993, 22 years ago – while the last one only heard about it somewhere in 2014. This on-going process indicates that people are still becoming aware of and hearing of green IT. A study also reported that it is imperative to start using various means to educate students about environmentally sustainable development (Ahmad *et al.,* 2013). The demand for awareness from interviewees were not only restricted to sustainable environmental development, but also to IT resource optimisation for green solution.

All the concepts of awareness and education did not come straight from proposition 1 only (raising an awareness on sustainability), but also from propositions 2 (the importance of sustainable green IT) and 3 (the role of universities on sustainable green IT). Though they come from different concepts and fall in with raising an awareness, it is imperative and worthwhile to categorise them within this link of proposition (raising awareness).

1) **Environmental awareness and education:** signifies an increased public awareness and knowledge of environmental issues. Some of the valuable comments related to this argument from interviewees were:

   "Promote the awareness of this subject and conduct research in the relevant field."[P8]

Even if the word "subject" in this first-hand statement is not clearly identified whether it is in relation to sustainable green IT or a sustainable environment it is firstly important for both of the subjects. Secondly, with the two comments from respondents' listed below, it becomes clear that it is also important for sustainable environmental development:

   "Universities, government authorities and even individuals should be environmental conscious. Individuals should make efforts to seek more knowledge regarding sustainability of the environment, while the government and universities should also step up their campaign aimed at promoting sustainable environment through seminars, promoting and supporting green IT RESEARCH through special funding." [P20]

   "Initiatives and awareness are the key strategies to promote sustainable environment."[P19]

2) **Sustainable green IT awareness and education:** discusses the actions that are being undertaken by students and staff members to raise awareness of green IT. It encompasses an awareness and education to the knowledge and practices of a wide range of IT software and hardware in order to address green issues and implement the green practice of designing, manufacturing, using and disposing of computers, servers and associated subsystems such as monitors, printers, storage devices, and networking and communication systems efficiently and effectively with minimal or no impact on the environment (Murugesan, 2008). As the following quotes from the interviewees plainly state, it is also important to educate people to be sustainable green IT aware.

> *"Educate the society on how to expose computer waste properly."[P3]*

> *"Educate the students their immediate consumptions, advocate for policy changes and initiate researches on green IT." [P4]*

> *"Universities, government authorities and even individuals should encourage research in the area of green IT, green IS, green computing, or sustainable green IT practices."[P17]*

As was indicated above, it is important for each individual on earth to understand the impact they have on the planet in order to become environmentally aware and change to sustainable green IT. Therefore, an educated student and academic staff can be one of the most powerful weapons in the universities' battle against harm to the environment. Therefore, introducing more courses related to environmental sustainability and sustainable green IT will help make society aware of the current environmental challenges.

Proposition 2:

The importance of sustainability: *(Why is green IT important to you?)*

Sustainable green IT is for the benefit of both the natural environment and human beings. However, the degree to which people negatively impact their environment can undeniably be mitigated through several ways such as:

1) **Environmental responsibility or care:**

Molla *et. al.,* (2011) agreeing with Lamb (2009), define sustainable green IT as the way and practice of using computing resources efficiently, and as the activity of handling the environment with responsibility. In line with Molla *et al.* (2011), some interviewees highlighted the importance of environmental responsibility as cited below:

> *"It is important to me because I care about sustainability and preservation of our planet for the future generation." [P20]*

> *"It is important to take responsibility to look after the world God gave us." [P10]*

> *"The environment is important for it is our mother and improper disposal of equipment impacts the environment."[12]*

The capacity of green IT to mitigate the harmful effect of climate change imposes a responsibility on policy makers, and indeed all stakeholders of the Information Society, to promote the technology as an effective tool to combat climate change (Murugesan, 2008; Murugesan, 2010). Environmental responsibility is therefore the best way for an individual, as well as for universities, to get started and step up. Setting up universities to drive the effort for environmental protection while using optimised IT would be another step.

2) Environmental protection

Green Information Technology (IT) started as early as 1992, when the Environmental Protection Agency (EPA) created Energy Star, which is a voluntary labelling programme that supports organisations and helps individuals save money and protect climate change through superior energy efficiency (Gingichashvili, 2007). Environmental protection is not only required by the government and IT professionals; it is also critically important for the protection of South Africans' public at large, and in particular the protection of students and the health status of staff and the environment upon which they depend. The interviewees explained several ways of environmental protection for the benefit of society at large:

✓ For the sake of saving energy (reduce consumption of energy)

> *"Because, the world is short of resource and this will help a lot to save energy particularly in SA as we are very short of electricity and most comes from coal which is a highly polluting source." [P1]*

> *"It promote energy-efficient compute, communication device, low electromagnetic emissions, safe disposal and recycle of old electronic devices etc."[P8]*

✓ For the sake of saving precious resources (reduce consumption of resource)

> *"It is important because we don't have unlimited resources, somebody must pay for consumed or completed energy." [P9]*

> *"Green IT is important because it encourages conservation of unique natural resources."[19]*

✓ For the sake of having clean air (reduce carbon footprint) or fighting pollution

> *"It protects the environment in reducing their carbon footprint for several reasons."[P11]*

3) Environmental impact

There are generally two causes of global warming and climate change (environmental impact): natural causes and anthropogenic (human) causes, as described in detail in Chapter 2 section 2.4. The Geological Society of America (GSA, 2006) agrees with the assessments of the National Academies of Science (2005), the National Research Council (2011), and the Intergovernmental Panel on Climate Change (IPCC, 2007a) that the global climate has warmed and that human activities (mainly greenhouse gas emissions) account for most of the warming since the middle 1900s. The interviewees understood the environmental impact due to the human cause in putting much carbon in the atmosphere when they burn coal, oil and gas or cut down forests; they noted the importance of green IT in giving benefits for mitigation of environmental impact as follows:

"Because it minimizes the impacts of pollutions" *[P2]*

"It is important to me because it help our society and world affecting from climate change and global warming. It also helps to manage toxic waste from computer equipment that pose damage to our society or world."[P3]

4) Environmental policy

An environmental policy is an agreed statement from top management of an organisations' overall performance towards the environment in which it operates (ISO 14001 standard). The respondents, referring to the commitment of an organisation to the laws, regulations, and policy concerning the environmental issues raised some important points as well:

"Not particularly important personally, but I believe that the university should implement green IT policies, particularly with regard to recycle and paper usage." *[P7]*

"Follow the regulation of environmental policy." *[P19]*

Improving overall environmental performance in all its operations and process is a fundamental principle to the academic institutions. Generally, interviewees agreed that policy makers have to promulgate laws that would improve energy policy, and stated that pushing universities to adopt sustainable business practices on a global level, can bring real change.

5) Clean environment

Afforestation, reforestation and forest management (forestation) play a great role in reduced deforestation, purifying air, improving water quality, keeping soil intact, and providing food and medicines for human being and animals (FAO, 2008). Besides, technology also helps the carbon capture and sequestration method to reduce greenhouse gas emissions (EPA, 2013c) as stated particularly by [P5].

> *"It is important because it minimizes the impacts of pollutions."* ***[P2]***

> *"It is important because it helps to keep the environment clean by achieving carbon neutral status through annual offsetting."* ***[P5]***

The removal of CO_2 which is known as "sequestering" or "offsetting" directly from the organisation or utility plants to store it in secure reservoirs can be motivated in all campuses, as CO_2 is one of the main contributing elements to the greenhouse effect. As a treatment process to reduce carbon emissions more trees can be planted all over campuses. Trees use the energy of sunlight and convert carbon dioxide and water into carbohydrates and oxygen through a process called photosynthesis. Hence, planting trees around campus has environmental benefits. Besides producing oxygen and removing carbon dioxide and pollutants from the air, trees have also many other social, economic and environmental benefits.

Proposition 3:

The role of university on sustainable green IT: *(What role should universities, government and even individuals play in an over all sustainable green IT*

The findings of the role and responsibility of university and government in promoting sustainable environment are summarised as follows:

- ✓ Doing research on sustainable environmental development and sustainable green IT practices:

"Research is important. Universities should get finding programs through the National Research Foundation (NRF) or other programmes to focus researchers' attention. **[P1]**

"Advocate for policy changes and initiate researches on green IT" **[P4]**

"Universities, government authorities and even individuals should encourage research in the area of green IT, green IS, green computing, or sustainable green IT practices." **[P17]**

✓ Each and every person must take environmental responsibility:

> *"Everyone must take responsibility diligently."* **[P16]**

> *"Each and every one should be responsible of environmental impacts and needs to fights in creating new means of generating energy for efficiency."* **[P18]**

✓ Educating student and academic staff:

> *"Educate the students their immediate consumptions."* **[P4]**

✓ Implementing safe energy:

> *"Energy efficiency is an important issue. It benefits the organisation and individuals in many ways such as environment, finance and so on."* **[P8]**

✓ Providing safe waste bins and avoid exposing toxic materials:

> *"Government and universities should provide waste and exposer areas for recycling"* **[P3]**

✓ Introducing laws and regulations on green procurements (green policy):

> *"Universities should have "green" policies from procurement throughout to recycling and disposal. In the same way the individual has also to fall in the line."* **[P7]**

> *"By implementing green IT policy universities will preserve their resources and lower their consumptions."* **[P2]**

> *"There should be policies implemented by government and these policies should be followed by universities, authorities and individuals."* **[P12]**

Finally, the respondents opined that universities and government as organisations and even individually have to promote a sustainable environment by way of doing research that is

aimed at the study of sustainable green IT in order to find programs through the National Research Foundation (NRF). Besides, each and every one has to contribute by avoiding exposing toxic materials and saving energy, managing e-waste disposal, educating the students and academic staff members on how to expose computer waste properly were also stated. Lastly, the interviewees demanded a set of conventional principles and procedures that are considered binding on students and staff members of the universities to be promulgated to adhere to the environmental policies.

> **Proposition 4:**
>
> **Green IT policy and practice** (**Complying with green IT policy**): *(How can a university develop a green policy and practices to promote sustainable products and resources?)*

The organisations strategy and goals must be clearly defined with a Green IT strategy to realise business and goals (Uddin and Rahman, 2012). In respect to this statement, interviewees made some vital suggestions complying with sustainable green IT policies and practices.

> *"University can develop sustainable green IT ethics and national recognitions policies if it adheres to the environmental policies such as sustainable design, sustainable procurement, pollution reduction and conservation of resource."* ***[P2]***
>
> *"Develop policies that will encourage companies to recycle, reduce and re-use from the work area environment."* ***[P3]***
>
> *"Implement standards, regulations and cooperate with organisations that advocate green IT ethic implementation."* ***[P8]***
>
> *"Implement green IT solutions as a way of saving costs (Print paper, electricity etc.)."* ***[P13]***
>
> *"By purchasing eco-labelled products and following the environmental policy acts."* ***[P17]***

What is currently being done about green IT policy and practice in the university was discussed in this section of the proposition. Some summarised important points drawn from these explanations are:

A university can develop sustainable green IT ethics and national recognition policies and practices if it adheres to the environmental policies of sustainable design, sustainable procurement, pollution reduction, conservation of resources, reduction of hazardous materials, improvement of energy efficiency that will help reduce power consumption and promote the biodegradability of unwanted and outdated product. As also stated in literature review products with environmental reporting and certification, like EMAS II product certification, and environmental product declaration was highly suggested.

Other respondents also cited the significance of understanding and education. Thus, educating university communities on the need to expose computer waste, organise exposable areas and develop policies that will encourage university to recycle, reduce and re-use the products were proposed to be implemented. Making environmental policies mandatory in all curricula, making research possible and providing periodic pamphlets and posters that assist to raise environmental awareness were also stated.

[P9] explained good management in a short and simple: *"garbage in is garbage out"* similar to *"what you see is what you get" or "what goes comes around"*. This expression is used in computing and other fields, to denote that incorrect or poor-quality input will produce faulty output. A somewhat different suggestion was also specified by **[P20]** in saying a university should engage in "behavioural research", in order to find factors that affect the policies implemented or factors that will affect the policies they intended to implement regarding green IT practices. Finally, policy makers should lead or live by example, was also stated **[P5]**.

> **Proposition 5:**
>
> **Hardware and software efficiency**: *(What new green IT resources and systems should be used in transforming the current use of IT resources and systems operations to make universities greener?*

Interviewees were asked what input they have for IT hardware and software optimisation in transforming the existing use of computer components with regard to ecological aspects. In addressing this issue the interviewees suggested the optimisation process of hardware and software efficiency as follows:

1) **Hardware efficiency:**

*"Switch from hardware or equipment that consumes a lot of energy and pollutes the work area (CRT versus LCD), or compare the efficiency of video cards and processors."***[P2]**

"Deploy energy-efficient products." **[P8]**

"Resource equipped with recyclability, eco-friendly devices and less costly software should be used." **[P11]**

"Redesigning of data centre and the greening popularity of utilization with green networking and cloud computing" **[P15]**

The literature review Chapter 2 section (2.7) described a variety of hardware and software solutions for conserving energy and enabling IT optimisation for a green environment. Based on that several empirical data were acknowledged, amongst others the following were highlighted:

Care should be taken both with the purchase and post-purchase (use) of equipment. The improvement of hardware or related-equipment that consumes a lot of energy and pollute the work area was also identified. Replacing high energy-consuming hardware, for instance CRT with LCD, and other intensive energy-consuming equipment by energy-saving equipment, and purchasing energy-efficient devices that use sustainable energy and are eco-friendly was also mentioned. Choose to use LED screens rather than intensive power-consuming monitors, portable rather than bulky and so on were among the criteria of hardware and software efficiency requirements. Besides these redesigning the data centre and popularising of the utilization of green devices and green networking and cloud computing was the main strand of the interviews.

2) **Software efficiency**

"Care should be applied both to purchase and use of equipment. Energy-saving routines that reduce power use when the machines are inactive should always be installed." **[P1]**

"Use software that follow green algorithm, improved power management and improved virtualization." **[P18]**

Compute when only necessary for computing. Stop watching movies, using Facebooks and other social media because the network is designed for

communication not for entertainment. Games and social media makes the network busy and engages with lot of energy consumptions. Surfing YouTube, Facebooks all the day are not supportive."[P9]

The issues raised on software efficiency are: Using software that follow green algorithm, improved power management and virtualization such as desktop virtualization, smarter grid, ERP System and cloud computing to reduce the amount of servers. Computing when only necessary for computing was also mentioned as a policy for quality and efficiency measures. To mitigate this perceived risk, the interviewees proposed to incentivize investments in infrastructure to connect the unconnected and enable more students and staff member, across all income segments, to gain access to ICT.

Proposition 6:

Implementing dynamic learning: (*What approaches and methods of green IT practices should be adopted and implemented in universities to create a dynamic learning experiences and ways to reduce environmental pollution, impact, carbon footprint and degradaton?*)

Academic staff members and students were asked how dynamic learning could contribute to the quality of education and benefit the society in a way that doesn't affect the environmental sustainability. Some of the important argument stated were:

1) **Conversion to digital document:** Going paperless is a greener option than using quantities of paper. Although it is difficult and almost impossible to totally eliminate paper the cut down on paper use saves money and reduces operational carbon footprints.

   "Use of web conferencing and other possible means of electronic like distance learning that supports paper cut edges are advocated." [P12]

   "Identify paperless opportunity, realize operational carbon footprints and use extensively dynamic learning."[P19]

2) **Adoption of virtual classrooms:** That allows the academic staff and student to communicate, share and interact with one another and engage with resources in work groups.

"Awareness and electronic tools of learning materials should be initiated." **[P6]**

"Use cloud computing, virtual computing and ERP systems." **[14]**

"Implement BYOD's strategy which helps students or encourages students to learn within and outside the classrooms. This enhances the productivity of students, since they can use their personal devices which they are familiar with to access educational materials from any location within and outside the campus and at any time. BYOD also allows the use of personally owned mobile devices in the classroom." **[P16]**

"Using virtualization technology that enable to reduce equipment and system management costs." **[P17]**

3) **Adoption of telecommuting and video-conferencing:** The value of academic staff members and students not having to travel to campus and work if it is not absolutely necessary to be there in person.

"To increase productivity and improve working environment area in terms of sustainability, tele commuting, web conferencing could be one of the technics to dynamic learning and to reduce travel" **[P2]**

To increase productivity and improve the working environment in terms of sustainability, telecommuting (teleworking) and distance learning (e-education) were chosen in supporting cutting down on paper use and realizing the impact of operational carbon footprints. Besides, cloud computing, web conferencing and virtualisation networks that allow for the reduction of equipment and system management costs were identified as primary tools to dynamic learning.

The quantum computing issue was also raised by **[P9]**: to enable solving all the possible questions. That means, no multiple answers to multiple questions. The other technique, the implementation of BYOD's (BRING YOUR OWN DEVICE) strategy, which helps students or encourages students to learn within and outside the classrooms, was also raised.

According to the respondent **[P20]** BYOD's strategy enhances the productivity of students, since they can use their personal devices which they are familiar with to access educational

materials from any location within and outside the campus and at any time. BYOD also allows the use of personally-owned mobile devices in the classroom.

5.4.3.2 Research question 2

In order to address the third core theme: e-waste disposal management, three propositions were addressed from the main research question 2:

> **Proposition 1:**
>
> **Obsolescence issue of divice:** *what should universities do with the obsolete devices once they have received the new computers and devices?)*

The university policies for disposal of the old computers and its related equipment were stated as follows:

Recyclability concerns:

The local governments and institutions of higher education in Malaysian have implemented various green computing campaigns aimed at promoting sustainable IT practices. Some examples of the measures include placing recycling wastes according to its type and classification (paper to paper, metal to metallic, glass to glass) in campuses that allow students to drop obsolete computing hardware and related electronic devices and other resources for everyday use (Ahmad *et al.,* 2013). The universities in South Africa probably have to develop similar or other ways of recycling processes and approaches as cited by interviewees.

> *"Follow proper recycling procedure (re-use reduce and recycle), without exposing to the public and the obsolete one should be disposed wisely."* ***[P3, P19]***
>
> *"They should have an arrangement with new computer suppliers on this issues. The obsolete equipment should go to the designated professional processing agents."* ***[P8]***
>
> *"If the old computer cannot be re-used, it should be recycled or disposed of in an environmentally-friendly manner."* ***[P17]***

"I think obsolete computers should be returned to the manufacturers who have programs regarding recycling of obsolete computers." [P20]

Donation to underprivileged class (Re-use)

EPA (2014) encourages consumers to donate old computers in order to conserve natural resources and avoid greenhouse gas emissions and water pollution.

"Recycle safely or donate to needy institutions such as rural schools." [P7]

"Donate to Non-Governmental Organisation (NGO's)." [P10]

"Give them to schools or else recycle them." [P12]

Reclaim the resale value (residual value)

Electronics labelled as "e-waste" are not actually waste at all (zero-waste policy), but rather electronic equipment or parts that are ready to be resold for re-use or that can be recycled for the recovery of materials. (EPA, 2013b)

"They should recycle them and reclaim the gold or else donate to schools and projects."[P9]

"Recycle the recyclable parts of computer (e.g. copper, steel and plastic), or donate old computers to unfortunate people or else safely dump according to national regulations/laws the non-recyclable parts." [P14]

"Donate to disadvantaged schools so that someone else can use it or resell it to retrieve important components." [P18]

It is required that the universities' computers and peripherals that no longer have value to them either be disposed appropriately or donated, resold or recycled, within the limits of the procedures. Tons of e-waste is disposed of annually, by all universities. South Africa, like most of modern society relies heavily on IT and computers for operational life. Therefore, best practices of e-waste management must be applied as well as measures such as (1) recycle (e.g. copper, steel, plastic) re-use and reduce or incinerate or donate to underprivileged or disadvantaged schools (i.e. rural school, non-governmental organisations (NGO's), or (2) sell obsolete computers to manufacturers who have

programs of recycling and reclaim the gold the products contain. All terms considered, e-waste must be recycled responsibly without exposure to the public.

> **Proposition 2:**
>
> **The scenarios of the university on buying eco-labelled product:** (*What should the scenarios of the universities be for buying eco-friendly ranges of products that are aimed at reducing e-waste generation conserving energy and resources?*)

Green procurements incorporate a broad range of activities, including product modification, packaging changes and, modifying advertising. In this section interviewees were asked what the scenarios of the university on purchasing eco-labelled products could be. The scenarios of the universities on buying eco-labelled products are explained in the following items:

> *"The University should give consideration for buying eco-friendly range of products that aims at reducing the e-waste generation and conserving resource when issuing tenders for IT equipment."* **[P1, P2, P3, P7, P11, P12-P20].**
>
> *"Purchase Energy-efficient product. Besides, the products should also be recyclable components."* **[P4]**
>
> *"Buy from green IT certified organisation and ensure they are recyclable too."* **[P6]**

The University should consider buying an eco-friendly range of products that are aimed at reducing the e-waste generation and conserving resources and energy when issuing tenders for IT equipment, for instance purchasing energy-efficient equipment ensuring that products contain recyclable components (purchasing eco-labelled product) or products and services from green IT certified organisations especially locally made products that cause minimal adverse to the environmental impact and promote efficiency and environment-friendly products. It is important to invest in eco-friendly devices even they costs more, as they benefit in the long run. Government was requested to incentivize "green purchasing". Finally, when buying eco-friendly products universities were recommended to consider

about three things that matter most 1) test whether they are functional, 2) consider portability or midrange computers and finally 3) they have to be economical.

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Proposition 3:

Reasons for discarding obsolete electronics: (*What are the possible reasons for discarding the old computers or devices at your organisation?*)

</div>

The possible reasons for discarding old computers and IT equipment are the hardware and software spiral requirements, the need of users that rise with compatibility issues of standard platforms (e.g. the new MS Office 2015 requires new equipment). Some other reasons such as damage, power failure, outdate (obsolescence), constantly faulty, unreliability, quality, speed, efficiency, flexible designs, having more functionality and affinity to newer technology are mentioned.

> *"The hardware and software spiral is key, and the need of users rise with it. Sometimes compatibility with standard platforms (e.g. MS Office) requires new equipment."* **[P1]**

> *"Faulty, damage, power failure, compatibility software issue and affinity to newer technology."* **[P5]**

> *"Because of the newly manufactured PCs availability which are much faster and efficient than the old ones."* **[P15]**

> *"Because new technology are coming with new upgrades and flexible designs."* **[P18]**

> *"The availability of having more functionality in new technologies make the old equipment to be discarded."* **[P19]**

5.4.3.3 Research question 3

In order to address the fourth core theme: energy efficiency and carbon footprint reduction, three propositions were addressed from the main research question 3:

As more IT professionals are put under pressure to ensure their IT investments are made in eco-friendly manner, a common objective is to assess and possibly reallocate resources for green (Molla *et al.,* 2009). Following this, it was suggested by several respondents that green policy makers, in helping the university to reduce IT power consumption or improve energy efficiency, apply some reduction methods in energy consumption, such as: in-service training, waste not decisions (activities of turning on and off, when they are not in use) improve lighting systems and performance matters. Finally, IT policy makers have been encouraged to adhere to the institutional system policy requirements.

> *"Green IT policy makers need to follow the energy star initiatives and the policy of sustainability."* **[P1]**

> *"To reduce IT power consumption and advocate the use of green technology, green IT policy makers should conduct in-service training and switch off unnecessary equipment."* **[P4]**

> *"Centralized air condition systems used in our labs and offices are wasteful, they are meant to reduce energy consumption but I really doubt their efficiency."* **[P5]**

> *"Choose the right light, shut down computers when they are not in use and use a power strip to reduce your plug load."* **[P10, P17]**

> *"IT policy maker should play significant role in setting guideline for measuring the carbon footprint of the electronic product, activity and society."* **[P16]**

> *"Use smart grid technology."* **[P18]**

Interviewees recommend that a strategic approach to be implemented by green IT policy makers. The approaches are to follow the energy star initiatives and the policy of sustainability in playing a significant role in measure that will reduce the amount of energy

used for the activities and even reduce unnecessary resources, for instance 1) by encouraging and promoting green performance to all stakeholders and by forcing all users to think green, 2) by conducting in-service training and switch off unnecessary equipment in the learning environment, 3) by practicing the law implemented by the top management of the university in regulating the information disseminated from time to time, 4) by making individuals aware to shut down the workstations when not in use and applying a power strip to reduce plug loads, and lastly, 5) by using alternative energy sources such as solar panels, CS, wind power and switching to energy-saving light bulbs and efficient computing equipment. Eventually, the interviewees proposed the idea of using smart grid technology (power meters, voltage sensors, fault detectors, etc.) to be applied campus-wide for IT optimisation solution.

Currently, energy is consumed significantly in the manufacturing, operation, storage, and cooling systems mainly due to large number of computing that various organizations including higher educational institutions now depend on (Aggarwal *et al.,* 2012). **[P5]** indicated that centralized air condition systems used in LANs and offices were wasteful. As **[P5]** noted in his own words "Centralized air condition systems used in labs and offices, though they were meant to reduce energy consumption, he was really doubt of their efficiency". Possibly, we can predict that he was looking for green fan systems that can be upgraded and adjusted to optimize the circulation of air in the most energy-efficient way. Energy efficiency is an important issue to reduce the impact on the environment. It results in less money spent on energy by offices and benefits the organization in measuring the carbon footprint of the electronic product, activity and society. Cooling systems in various organizations that depend on IT consume a large amount of energy, and this can be lessened by leveraging local climates and using chilled loop and free cooling strategies (Aggarwal *et al.,* 2012).

> **Proposition 2:**
>
> **Alternative approach towards improving energy and reducing consumption:**
> *(What other aternative approaches of improving energy-efficiency techniques or means of energy-saving practices could be implemented to reduce consumption)*

As an alternative approach towards improving energy efficiency, the replacement of non-renewable energy with renewable energy for the sake of consumption and pollution was supported by the focus group.

> "*Universities that runs heavy IT Operations on daily basis are sapping energy continuously, therefore, by implementing renewable energy such as solar power, energy power etc. will reduce their carbon footprints tremendously.*" **[P2, P4, P8, P11-P13, P16, P18 and P19]**

> "*Universities to reduce both their operational cost and IT power consumption with in their business need to advocate an implementation of bring your own device (BYOD or use solar system or learn to switch off all unused workstations during working hours and after hours.*"**[P3, P5, P20]**

> "*Utilize the solar energy and government should subsidize on the high starting cost on this type of devices in order to promote it.*" **[P8]**

> "*Switch off unnecessary equipment during non-working hours. Invest in solar energy. Africa has the sun throughout the year.*" **[P14]**

> "*The energy star was launched as a means of helping organisation, save money and reduce greenhouse gas emissions by identifying products that offer superior energy efficiency.*" **[P15]**

As indicated clearly in the above comments, universities that run heavy IT Operations on a daily base are sapping energy continuously; therefore, by implementing measures to implement renewable energy such as a wind electrical system, solar electrical system and hydro-electrical system as an option to non-renewable energy will tremendously reduce the use of fossil fuels (coal, oil and natural gas) that negatively impact on natural resources. Universities that work on reducing both their operational cost and IT power consumption within their business need to advocate an implementation of bring your own device (BYOD) strategy in order to eliminate duplication of devices, which effectively helps reduce the number of devices that use up electricity in a work environment. Other approaches for improving energy efficiency are highlighted as 1) utilizing the solar energy, for Africa has the sun throughout the year, 2) using wind power or hydro-power or bio-fuels that create a healthy indoor environment, and implement natural ventilation systems and finally 3) Learning to switch off all unused workstations during working hours and after hours to reduce the amount of energy.

In order to be transformed into alternative ways of using energy, universities ought to be subsidised by government for the start-up cost of new devices. Top-level green IT policy managers were identified as the most important persons for the initiation of alternative approaches to improve energy consumption (top-bottom approach level). Suggestions such as following the Energy Star regulations, providing a benchmark for the school's emission reductions, were stated by interviewees; in order to help organisations save money, reduce greenhouse gas emissions and identify products that offer superior energy efficiency.

According to respondent **[P1],** the new mathematical science building of his campus has been designed as a green building to minimize energy use. This could serve as an example to other universities to build their rooms as green and energy saving with proper air conditioning systems to reduce pollution and improve efficiency.

> **Proposition 3:**
>
> - **Reduction of carbon footprint techniques:** (*What measures should IT leaders and users implement in pursuing green IT resources, systems and operations in relation to carbon footprint to make univerities much green?*

Herrmann *et al.* (2012) state that in the last two decades, carbon emissions have raised focus on being able to measure the amount of greenhouse gas emitted by human, activity, products and organisations. Therefore universities as large organisations, need to advance sustainability. It is also a factor in decision making and has an impact on competitiveness. Nowadays, choosing a product is not only based on the price or the quality of service, but also on its carbon footprint.

> *"IT leaders should take green service delivery as well as green service administrations." [P2]*
>
> *"Regulate printing of papers and provide central approach to the usage of computers" [P4]*
>
> *"Set up proper central control, guidelines for monitoring the running of the resources" [P8]*

"Have policies that ensure employees do not over utilize resources and power." *[P12]*

"By benchmarking the present number of greenhouse gases generated, IT policy makers will be able to develop an appropriate strategy for reduction." *[P17 and P19]*

"Implement auditing and controlling methods to identify who are the highest energy consumers and emitters on campus to make substantial contribution in reduction carbon emissions." *[P18 and P20]*

To regulate abuse of resources and the carbon footprint of the campus some guidelines were stated by focus groups, such as:

- ✓ Regulate the printing of papers and provide a central approach to the use of computers.

- ✓ Set up proper central control, guidelines for monitoring the running of the resources. Audit the systems on use of power consumption and utility abuse.

- ✓ Stop watching movies, using Facebooks and other social media, because the network is designed for communication not for entertainment.

- ✓ No fun at higher educational level, for games and social media make the network busy and consumes a lot of energy.

- ✓ Have policies that ensure employees do not over-utilize resources and power.

- ✓ Implement "Green" carbon footprint auditing.

- ✓ Conduct seminars, conferences and workshops about all relevant topics such as the ecosystem, forestry, natural resources, alternative use of powers, conservation, environmental ethics and sustainable business.

- ✓ Switch to other fuels because using fuel with a lower carbon contents is a way to reduce carbon emissions.

- ✓ Implement of auditing and control methods to identify who the biggest energy consumers on campus are could help IT leaders to a make substantial contribution in reduction carbon emissions.

In order to effectively address carbon emissions, IT leaders ought to focus on energy efficiency because efficiency improves air quality and reduces carbon footprint emissions.

Universities can implement carbon management solutions to detect the operational electronic emissions. Carbon management tools can transform data collection and analysis, helping universities meet their sustainability goals faster and improve the accuracy of reporting to stakeholders (Herrmann *et al.,* 2012).

5.4.3.4 Research question 4

In order to address the fourth core theme, cost benefit relevance, three propositions were addressed from the main research question 4:

> **Proposition 1:**
>
> **Start-up cost issue:** *(How will the start-up cost affect the university as the result of rapid technology change designed to lower energy consumption considerably and improving efficiency?)*

The data express a considerable need of support for start-up cost. Most of the interviewees agreed on start-up financial aids.

> *"Obviously the start-up cost can be large financial burden for universities and can impact lecturers and students, however, by implementing green IT practices universities can free up capital that can be redistributed into improved services or product development." [P2, P4, P5, P8-P12, P15-P19]*

> *'The University will be affected economically such as training staffs and changing adaptations.' [P3]*

> *"The start-up cost need to be offset by future savings and incentivization." [P13]*

> *"The high start-up cost will affect not much. There is no need in new technologies what is needed is energy-saving technology and this is already on the market, as IT is even cheaper (e.g. cloud computing and virtual computing are cheaper than redundant." [P14]*

As green IT has become faster, cheaper and more inclined to innovation, obviously the start-up cost can be a large financial burden for universities and can impact lecturers and students. However by implementing green IT practices, universities can free capital that can be redistributed into improved services or product development. The university will

obviously get affected economically during the initiation period of green IT products such as training staff members and changing adaptations, but even if it is expensive, it is cost-worthy it will eventually help to promote sustainable environmental management.

Initially, the cost of green tech is high, but this should be weighed up against the greater good of humanity. Besides, it can have a positive impact in the long run, such as cutting edges, computers will be quicker with less power use, services will improve through the reduction of costs and machines, devices will transform into cloud computing and virtual computing which is cheaper.

Green IT could generate many benefits, more than the negative effects. Even if it will affect the budget of the campus during the initial implementation of green IT, in time to come it will visibly benefit the economy of the society as such and contribute greatly to the income of the university. This cost might vary from start-up cost to post-implementation value; therefore, the only way to know the advantages and disadvantages will be by comparing costs.

> **Proposition 2:**
>
> **Benefits of sustainable green IT:** (*How will green IT improve the envronmentl management capabilities and streamline business processes to make the university both greener and profitable?*)

There are many benefits of sustainable green IT to the society and the environment. These examples that emanated from interviewees show that profit can be aligned with environmental sustainability.

Theme 1: Sustainable environmental development

1. Improve environmental preferable business.

2. Save natural resource.

3. Create clean environment.

4. Place the citizen at the heart of a sustainable and digital economy.

5. Create a hopeful and prosperous future.

Theme 2: Sustainable green IT practice

1. Green design that adheres to the environmental policy.

2. Green data centre that enables the power to connect billions of users.

3. Cloud computing that allows to reduce the product use.

4. Improvement in the quality of life, health and well-being.

5. Improved ventilation rates.

6. Reducing CO_2 concentrations.

Theme 3: E-waste disposal management

1. Safe disposal method (Re-use, reduce and recycle).

2. Identify type of e-waste.

3. Examine potential risks of e-waste.

4. Identify source of e-waste.

5. Arrange for safe collection centre.

6. Identify safe means of transportation.

Theme 4: Energy efficiency and carbon footprint reduction

1. Clean energy.

2. Energy efficiency (energy-saving technique).

3. Lower power consumption = lower electricity bill.

4. Reduce pollution.

Theme 5: Cost-analysis relevance

1. Save money (cost benefit).

2. Reduce the cost of unnecessary resources.

3. Promote quality service (green job).

4. Have eco-labelled branding identity.

5. Improved market performance and competitiveness.

> **Proposition 3:**
>
> **Measure the readiness of sustaianble green IT:** (*How can the readiness of green IT into university be measured and explained?*)

Several organisations across the world are challenged with these problems, such as: budgeting processes that fail to account for sustainability initiatives' benefits; policy maker teams whose goals are not in line with those of the sustainability teams; and not knowing about how to implement metrics that correctly account for external environmental costs. With respect to the proposition of measuring the readiness of sustainable green IT, some vital clarifications were acknowledged.

> *"It can be partially measured by the usage of electricity or lack of new devices."* ***[P5]***

> *"Monitor the implementations of the policies and regulation closely."* ***[P8]***

> *"If you cannot explain, it is simply nonsense."* ***[P9]***

> *"It does not matter how many resources you have, if you don't know how to use them, they will never be enough."* ***[P10]***

> *"The readiness can be assessed through: 1) Is funding available? 2) Is there onsite renewable energy? 3) Tapping on renewable grid power."* ***[P15]***

> *"Through evaluation of product end of life and asset disposal, procurement policies, and supply chain issues."* ***[P16]***

Suitable metrics should be developed, tested and applied in assessing the product from manufacturing stage to its disposal, procurement policies and supply chain issues. It can be partially measured by the usage of electricity or lack of new devices. Demonstrable statistics regarding paper use and recycling electronics can be done to measure the readiness, as paperless policies could have an impact on paper cost or consumption. Monitor the implementations of the policies and regulation closely by assessing the practice and policy of environmental effects on each university activity on an annual basis and by conducting research on all activities.

Particularly as **[P15]** described, there are many tools available on the market that can be used to measure green IT practice such as 1) capital budget decision of funding availability 2) on-site renewable energy systems 3) Tapping on renewable grid power and so on. Having accurate knowledge and having a common and good understanding, can measure the readiness of green IT practice. To support this argument especially **[P9],** quoting from Albert Einstein, explicated the importance of understanding in saying *"If you cannot explain, it is simply nonsense"*. The readiness of sustainable green IT can be measured as well through the power of acquiring knowledge as well, as defined by **[P10]:** *"It does not matter how many resources you have, if you don't know how to use them, they will never be enough"*.

[P2] described the readiness of green IT, as the initial phase but not yet completely implemented. **[P4]** indicated the readiness of green IT as quite challenging, and mentioned that no initiative from the top was established at all. According to **[P12]**, the university still would have to create policies and implement them, mainly practical examples implemented by top to bottom approach management. Nevertheless, as indicated above, most of the interviewees provided sufficient valuable input on how to assess the readiness of sustainable green IT practices with the exception of very few who were not sure on how to measure the readiness **[P1 and P20]**:

> *"Suitable metrics should be developed, tested and applied. But I am not knowledgeable about it."* **[P1]**

> *"I think behavioural research can help."* **[P20]**

Further comments on green IT practice

Among the twenty interviewees, only three persons disclosed further information when asked what they would like to add about green IT practices. The other 17 only answered the provided format questions. The further suggestions and recommendations provided by the three was about conditions such as: we need to talk more about green IT in different media, TV, Radio, Newspapers as well as university weekly newspapers. Students and staff members should also be made aware, as IT contributes 2% of human greenhouse gas emission in the world. Finally their suggestion was: to significantly emphasise the practice of green IT, everyone should play their unique role to promote the use of IT equipment for a greener environment.

5.5 Correlation analysis of the grounded theory with respect to research findings in framework development

The basis for the development of this framework is derived from the grounded theory method, focus groups and literature review. However, the articles provided in the literature review are not given in any specific order on how they contributed to the development of the new framework.

Theme 1: Sustainable environment		Focus group interview	Literature source
Environmental awareness and education	1. Promote and encourage environmental awareness and education.	*"Universities need to promote awareness, launch education and conduct research in the relevant field"* **[P8]**	Environmental sustainability is a persisting problem and it is an unavoidable issue for conversation. Universities need to address and reassess this urgent matter in the spirit of creating awareness of the sustainable green IT for healthy environment and effective use of technologies, and of course, to adequately prepare learners and teachers for proficient practice. The research area of green IT is blossoming as both academics and practitioners look for innovative ways of using systems to help achieve environmental sustainability objectives (Melville, 2010).
	2. Educating the new generation about the real danger of climate change and global warming.	*"Universities, government authorities and even individuals should be environmental conscious. Individuals should make efforts to seek more knowledge regarding sustainability of the environment, while the government and universities should also step up their campaign aimed at promoting a sustainable environment through seminars, promoting and supporting green IT RESEARCH through special funding."* **[P20]**	
	3. Allow students and academic staff members to engage in diversity of environmental fields		
	4. Introduce core subjects about environmental sustainability		

Environmental policy	Empower or enforce environmental policy and acts	*"Follow the regulation of environmental policy."* **[P19]**	McCabe (2009) affirms that adoption of environmental policy is based firmly on the strategy of mini, medium and large size market progressive companies.
Environmental protection or preservation	Protect the environment on which individual depend to save its energy and precious resources and reduce carbon emissions.	*"It is important because we don't have unlimited resources; somebody must pay for consumed or completed energy."* **[P9]** *"Green IT is important because it encourages the conservation of unique natural resources."* **[P19]**	Going green in infrastructure and manufacture is one of the environmental protection practices that supports and promotes the use of processes that are environment-friendly, responsible and resource-efficient throughout (Conn, 2011).
Environmental responsibility or care	Manage environment with responsibility and care.	*The environment is important for it is our mother and improper disposal of equipment impacts the environment."* **[P12]** *"It is important to take responsibility to look after the world God gave us."* **[P10]**	Molla *et al.,* (2009) define sustainable green IT as the way and practice of using computing resources efficiently, and as activity of handling environment with responsibility.

| Environmental impacts | Assess the environmental impacts on air quality, water usage and toxicity adverse to human life. | *"It is important to me because it helps our society and world affecting from climate change and global warming. It also helps to manage toxic waste from computer equipment that poses damage to our society or world."[P3]* | Environmental problems are affected by both natural and human causes. Human activity is primarily responsible for the environmental impact (Weart, 2011; Anderegg et al., 2010; Oreskes, 2004) |
| Clean environment | Generate clean environment | *"It is important because it helps to keep the environment clean by achieving carbon neutral status through annual offsetting." [P5]* | Carbon management tools can transform data collection and analysis, helping organisations to meet their sustainability goals faster and improve pollutants of emissions (Herrmann *et al.,* 2012) |

Theme 2: Sustainable green IT practice		**Focus group interview**	**Literature source**
Sustainable green IT awareness and education	1. Promote and encourage sustainable green IT awareness and education. 2. Inspire students and academic staff members to do practical metrics on computer equipment use.	*"Research is important. Universities should get finding programs through the NRF or other programmes to focus researchers' attention." [P1]* *"Universities, government authorities and even individuals should encourage research in the area of green IT, green IS, green computing, or sustainable green IT practices." [P17]*	Educational institutions as organisations are responsible for sustainable educational materials and to provide students and lecturers with the information they need to understand fundamental environmental issues and to take measures that will help protect the earth from environmental depletion and damage (Ahmad *et al.,* 2013).

| Optimisation of IT for green | 3. Develop green design with increased efficiency and durability of products to reduce product effects through innovation and resource substitution.
4. Implement green manufacturing to ensure packaging process of electronic device in order to have little or no negative impacts on environment.
5. Switch to energy-efficiency data centres, sever virtualisation, cloud computing and cooling configuration to eliminate considerable amount of leaks.
6. Improve the algorithms of software programs to minimise the process needed to retrieve searching information.
7. Assess the effectiveness and efficiencies of the application software and social media websites to save time and electricity.
8. Strengthen printer output managements to cut back operational footprints.
9. Convert to digital documents.
10. Adopt virtual classrooms.
11. Adopt video-conferencing and web conferencing to reduce travel cost and pollutions.
12. Implement BYOD's (Bring Your Own Device) strategy. | *"Universities should have green policies from procurement through to recycling and disposal. In the same way the individual has also to fall in the line." [P7]*

"Develop policies that will encourage companies to recycle, reduce and re-use from the work area environment."[P3]

"Redesigning of data centre and the greening popularity of utilization with green networking and cloud computing" [P15]

"Switch from hardware or equipment that consumes a lot of energy and pollutes the work area (CRT versus LCD), or compare the efficiency of video cards and processors" [P2]

"Use software that follow green algorithm, improved power management and improved virtualization." [P18]

"Identify paperless opportunity, realize operational carbon footprints and use extensively dynamic learning" [P19]

"Use of web conferencing and other possible means of electronic like distance learning that supports paper cut edges are advocated" [P12]

"Implement BYOD's strategy helps students or encourages students to learn within and outside the classrooms. This enhances the productivity of students, since they can use their personal devices which they are familiar with to access educational materials from any location within and outside the campus and at any time. BYOD also allows the use of personally-owned mobile devices in the classroom." [P16] | Green IT is the application of environmental sustainability specifically throughout the Information Technology (IT) lifecycle (Molla *et al.,* 2009). It's the study and practice of designing , manufacturing, using and disposing of computers, servers and associated subsystems such as monitors, printers, storage devices, and networking and communications system efficiently and effectively with minimal or no impact on the environment (Murugesan, 2008), with a focus on e-waste minimisation and energy-efficiency maximisation (Watson *et al.,* 2008). |

Theme 3: E-waste disposal management		Focus group interview	Literature source
Recyclability	1. Manage e-waste disposal through recycling programs such as (recycle, re-use and reduce). 2. Know the volume of discarded e-products and identify the source of e-waste. 3. Reclaim the resale values (residual value). 4. Arrange for save collection centre, take back recycling programs to reduce landfills. 5. Provide techno trashes (e-waste deployment centre). 6. Identify save means of transportation.	*"If the old computer cannot be re-used, it should be recycled or disposed of in an environmentally-friendly manner."* **[P17]** *"They should recycle them and reclaim the gold or else donate to schools and projects."* **[P9]** *"Recycle the recyclable parts of computer (e.g. copper, steel, and plastic), or donate old computers to unfortunate people or else safely dump according to national regulations/laws the non-recyclable parts."* **[P14]**	The widespread use of electronic items has brought into focus many challenges. Everyday gadgets are adding physical distresses in human health as well as the rise problems of e-waste (Sabha, 2011).
Toxicity or hazardous materials	Identify toxic materials of e-waste to reduce risk potentialities.	*"Implementing green IT practice helps in reducing the use of hazardous materials, maximizing energy efficiency during the products life time and promoting the biodegradability of unwanted and outdated products."* **[P15]**	Over time, irregularly disposed electronic-toxic materials that are unsafe for the environment leak into the ground and oceans where they can contaminate the water that human beings drink and the plants human beings eat and on which the animals that live the area depend (Halfman and O'Neill, 2009)

Theme 3: E-waste disposal management		Focus group interview	Literature source
Life cycle assessment	1. Analyse products from cradle to grave phases. 2. Assess the proper acquisition of products for the sake of depletion and degradation.	*"The availability of having more functionality in new technologies makes the old equipment to be discarded."* **[P19]**	All products, not just technologies have an impact on the environment. This impact can occur at any time during the manufacture, use of the product or at end of life.
Longevity or	Identify product longevity through strengthen or production of quality process due to obsolescence.	*"Faulty, damage, power failure, compatibility software issue and affinity to newer technology."* **[P5]**	Manufacturing technology creates large amounts of waste, and obsolete computers and electronics get thrown out when they break or become outdated. (Halfman and O'Neill, 2009)

Theme 4: Energy efficiency and carbon footprint reduction		Focus group interview	Literature source
Save	1. Investigate energy-saving practices (power management, altering lighting systems, save mode and so on). 2. Invest in eco-labelled product certification especially in respect to energy efficiency (energy star).	*"To reduce IT power consumption and advocate the use of green technology, green IT policy makers should conduct in-service training and switch off unnecessary equipment."* **[P4]** *"Green IT policy makers need to follow the energy star initiatives and the policy of sustainability."* **[P1]**	Energy is a key factor in discussions of economic, social and environmental dimensions of sustainable green IT. Technology has carrying capacity to enhance energy efficiency across a wide range of activities. (Chevron Company, 2012)
Reduce	1. Replace energy intensive computer equipment and peripherals with less energy consumptions. 2. Apply the reduction of carbon footprint techniques.	*"The energy star was launched as a means of helping organization, save money and reduces greenhouse gas emissions by identifying products that offer superior energy efficiency."* **[P15]** *"Implement auditing and controlling methods to identify who are the highest energy consumers and emitters on campus to make substantial contribution in reduction carbon emissions."* **[P18 and P20]**	According to the US Environmental Protection Agency (EPA, 2010), if every home in America replaced just one incandescent light bulb with an Energy Star compact fluorescent light bulb (CFL), in one year it would save enough energy to light more than 3 million homes. That would prevent the release of greenhouse gas emissions equal to that of about 800,000 cars.
Improve	Smart grid technology has capability of reducing IT power consumption	*"Use smart grid technology."* **[P18]**	Sustainable green IT covers an enormous range of subjects: energy savings or conservation, energy efficiency and renewable

| Alternative use	Explore alternative energy sources for energy efficiency (saving) and energy reduction (consumption)	*"Implementing measures such as solar power, energy power etc. as an option to non-renewable energy will reduce their carbon footprints tremendously." [P8]*	energy that generate electric power from other sources of primary energy, reduction of carbon footprint and coal consumption, actively dealing with environmentally sustainable infrastructure design and e-waste disposal (Gingichashvili, 2007; Porter & Kramer, 2006).

Theme 5: **Cost benefit relevance**		**Focus group interview**	**Literature source**
Initial cost	Optimise market performance and competitiveness in supply chain	*"Obviously the start-up cost can be large financial burden for universities and can impact lecturers and students, however by implementing green IT practices universities can free up capital that can be redistributed into improved services or product development." [P2, P4, P5, P8-P12, P15-P19]*	Today, sustainability issues are increasingly becoming an important consideration in transforming the world's economies, industries, organisations, education and business models (Gingichashvili, 2007).
Green procurement	Purchase marketing and communications teams to sell product sustainability		

Table 5-3: *Selected case used in developing a sustainable green IT framework*

5.6 The generalised framework for sustainable green IT practices

Equivalent to a framework developed from literature review in chapter 2 and closely similar to the one developed in Chapter 4, the member checking of the focus group did not significantly change the core parts of the framework. Therefore, a proposed theoretical framework for measuring sustainable green IT practices emerged and was verified from the non-empirical frameworks developed in literature studies combined with empirical data obtained from the focus group. These measures of sustainable green IT practices are essentially theoretical by nature and deepen the body of knowledge. The empirical frameworks developed from qualitative empirical data mainly focused on case study research. The advantage of having frameworks based on case study research is that they provide wide-ranging insight into the phenomena being reconsidered; however, their generalizability and applicability is restricted.

A framework is a comprehensible system of interrelated objectives and fundamentals that recommends the nature and function of sustainable green IT practices. Understanding a framework enables interested parties to better realise the content provided by sustainable green IT practices. A theoretical framework based on the findings depicts five themes as shown in Figure 5-3, namely (1) the sustainable environmental development, (2) IT resource optimisation for green solutions (3) e-waste disposal management, (4) energy efficiency and carbon footprint reduction and (5) cost benefit relevance.
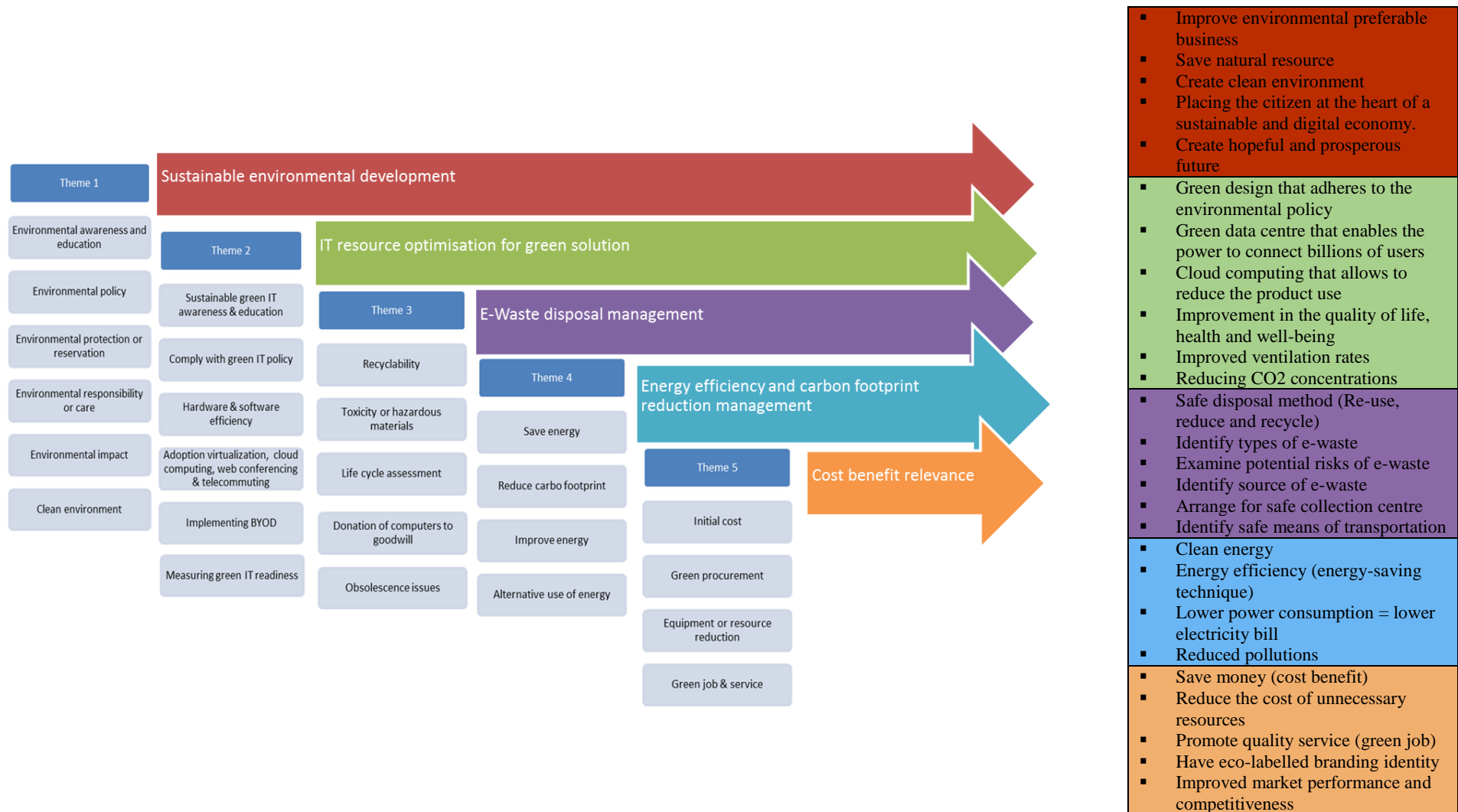
Figure 5-4: *Proposed green IT practices for South African universities*

- Who are the users of the framework?

The intended users of the framework are students, academic staff lecturers as well as employees who respectively learn, teach and work in South African universities. They are all responsible for sustainable green IT practice for the sake of the environment and drastic changes in the ecosystem which negatively impact even on human life. Besides, they all equally drive environmental sustainability processes and projects and have influence on the budgets. Furthermore, this management has a deep understanding of the environmental sustainability data, processes, analyses, reporting, foot printing, and risk management; including the associated opportunities and challenges. According to the great scientist Isaac Newton, "Each and every action on this Earth has an equal and opposite reaction." In the same sense, each human being is influenced by this reality.

- What are the unique problems addressed?

1) Human health impact

2) Natural environment impact

3) Socio-cultural impact

4) Global impact and

5) Resource sustainability.

The performance and practice of each technology option is evaluated using these broad categories.

- What are the preconditions to the framework?

The framework is planned for use in higher education institutions in general and particularly in South African universities, where they provide knowledge to society through the in-depth understanding of environmental impact. There are no restrictions to the use of this framework in terms of levels of education. Notably, the framework may require adaptations in order to be applicable to other education institutions.

- How should the framework be used?

The framework is for use by students and academic staff members as a tool for facilitating understanding and subsequent effective action relating to green IT practices. The framework allows students and academic staff members to focus attention on and allocate resources towards the optimisation of IT for green, both within cross-departmental

faculties and throughout other competitive university activities. The framework achieves its aims by exposing the key green IT concepts.

- What are the intended outcomes of the framework?

The intended outcome of the framework is a positive effect on the organisation's environmental sustainability transformation, both within the educational organisation and throughout the economy via education for sustainable development (ESD) or education for sustainability (EfS). Another outcome of the framework's use is an awareness of where to focus green IT practice and resources to optimally affect the aforementioned organisational environmental sustainability transformations.

5.7 Chapter summary

The main objective of this chapter was to find out the measures for sustainable green IT practice in South African higher education institutions through qualitative approach. Findings from focus groups conducted were presented and reported.

The chapter commenced on the initial generation of items for the sustainable green IT practice through a literature review (inductive analysis), and focus groups interviews (deductive analysis) to achieve valuable information from computer experts and professionals at South African universities. Five themes, namely sustainable environmental development, sustainable green IT practice, e-waste disposal management, energy efficiency and carbon footprint mitigation as well as cost benefit relevance have emerged from the qualitative analysis and the literature which constitute the green IT practices. A total of 30 items relating to the five themes were developed through a synthesis of the initial pool of items from similar studies and the original items revealed from the focus group interviews.

The next chapter systematically and in brief presents the findings, analysis, discussion and interpretation of the empirical results of this research in the form of tables and figures in order to answer the research objectives and questions.

CHAPTER 6

FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter provides a summary of the main conclusion reached in the analysis and discussions of data interpretation (Chapter 5). Additionally, it conveys answers to the critical questions that provoked this study and are stated in Chapter 1. The discussion and conclusion of the answer of the research question are based on the theoretical framework of this study and reveal whether the researcher has succeeded to address the critical questions that provoked this study.

Finally, the researcher demonstrates critical questions that are not addressed by the study and outlines limitations that contributed to this shortcoming. Last but not least, the research concludes with areas for further research and recommendations.

6.2 Summary of the research thesis

A summary of the research thesis endeavours to primarily address an overview of the statement of the problem definition, in what way the literature review was conducted how the theoretical framework was formed, the research methodology defined and data analysed. This applies also to the choice of data collection techniques that were when the overall objectives of the study are taken into consideration.

6.2.1 Review of research problem

Nowadays the computer is the most important instrument for everyone in the educational, commercial, corporate, bank and government sector. With the ever-growing need for newer technology as a matter of choice on smarter, smaller, and faster technology, electronic waste is also one of the fastest growing streams in the world. The South African local governments are faced with challenge of e-waste management and at the same time the Eskom crises fail to ensure continuity, consistency and improvement of energy efficiency. Therefore, the general problem is to investigate how IT is contributing to the environmental problems.

Earlier research reveals how green IT has significantly assisted and transformed organisational, commercial, corporate, bank and government sectors in many important ways (Watson et al., 2010). However, earlier research does not explain the measures and practices of green IT for environmental sustainability, with a focus on educational background, particularly in higher education institutions of South Africa; and this is the main research problem.

6.2.2 Review of literature research findings

The study necessitated the literature survey to define which aspects of the research problem have been researched in various places, in seeking clarity on subjects of enabling sustainable green IT practices and measures in universities of South Africa. Before the research could be executed, ethical clearance was obtained for the completion of the research. Assertion was given to the respondents that ethical issues in research such as the right to privacy would be supported.

The essential empirical information was obtained from both secondary and primary sources. Relevant information was collected from numerous publications, such as textbooks, journals and previous studies on the topic or subject. Additional and relevant local information was gathered by the use of interviews channelled to a targeted category or focus group. In this case, computer science and IT specialists, computer science and IT technicians, computer science and IT lecturers, green IT policy makers, green computing initiatives as well as computer science and IT post-graduate students were interviewed for an average period of half an hour.

6.2.3 Review of research objectives

This study aimed to assess the commitment to sustainability among South African universities in order to provide the best green practice within the different academic departments of a university. Cross-educational sustainability assessment tools can be a powerful drive for organisational changes. The objective of this study was to develop a framework for measuring sustainable green IT practices among South African universities. This was not an evaluation of how good each university are.

While much research has been conducted in different organisations, there is a lack of studies that concentrate on best green practice among universities. Research done on other fields of this area cannot be applied to other areas. Therefore it was necessary to further

investigate the study through research and education related to the environment. This problem under researched called for the need to conduct research focusing on managing e-waste disposal, exploring alternative energy sources for efficiency, and altering purchasing practice for IT assets to include sustainable criteria.

6.2.3 Data analysis and interpretations

The researcher used direct observations, document reviews, group discussion, grounded theory and interviews to gather data from diverse sources. This was done in line with the principle of multiple sources of evidences. For coding and analysing data, the study adhered to what Thomas (2003) described about procedures, preparation of raw data files, close reading of texts, creation of categories, continuing revisions and refinement within a case analysis and cross-case analysis.

 The researcher used the so-called ATLAS.ti 7 software to analyse the qualitative data. The entire codes and quotes are presented in appendix 7.

6.3 Summary of interview results

Core categories that emerged from the data were environmental sustainability, IT resource optimisation for green solution, e-waste disposal management, energy efficiency and carbon footprint reduction and the cost benefit relevance as independent variables. Chapter 5 detailed and explained the content and correspondence analysis summary of findings, following the grounded theory method. The content analysis provided basic descriptive statistics and the quantitative input into the more complex correspondence analysis. Findings were gathered from five randomly selected conventional universities namely UNW, UKZN, UP, Wits and UCT. All five of these higher educational institutions offered equally four respondents; the study was thus done with 20 respondents.

The results of the study discussed in the previous chapter will now be summarised in tables as follows in an attempt to give a bird's eye view on the findings of the study.

6.3.1   Environmental sustainability

Environmental sustainability is the core element that emerged from the interview data with the twenty respondents. All respondents confirmed that environmental sustainability has become a great concern to organisations in recent times. The issue of protecting the environment has become the main focus of the efforts various organizations are making to

adhere to an increased environmental responsibility according to all the interviewees. It has also drawn the attention of scholars, governments and non-governmental agencies, causing them to continuously make efforts towards tackling the problems facing the global environment.

1 Theme	Main objective	Findings
Sustainable environmental development	Measure sustainable green IT practice in universities in South Africa to reduce the environmental impact	➤ Promote and encourage environmental awareness and education. ➤ Educate the new generation about the real danger of climate change and global warming. ➤ Allow students and academic staff members to engage in diversity of environmental fields. ➤ Empower or enforce environmental policy and acts. ➤ Introduce a core subject about environmental sustainability ➤ Manage environment with responsibility and care. ➤ Protect the environment upon which all individuals depend to save energy and precious resources and reduce carbon emissions. ➤ Assess the environmental impact on air quality, water usage and toxicity to human life.

Table 6-1: Environmental sustainability

6.3.2 IT resource optimisation for green solution

According to the majority of the respondents, IT resource optimisation for eco-efficiency, involves green IT capability to create a sustainable environment. Sustainable green IT optimisation demands products to be manufactured from recyclable materials that are efficient and flexible in ensuring effective business.

2 Theme	Main objective	Findings
Sustainable green IT practices	Provide improvement on the acquisition, utilization and effectiveness of usage of technology in universities and critically evaluate the approach of creating a dynamic learning experience and develop a green IT model to establish a holistic approach to the use of green IT products, applications, services and practices.	➢ Promote and encourage sustainable green IT awareness and education. ➢ Inspire students and academic staff members to do practical metrics on computer equipment use. ➢ Implement green manufacturing to ensure the packaging process of electronic devices little or no negative impact on environment. ➢ Develop green design with increased efficiency and durability of products to reduce product resource substitution. ➢ Provide energy-efficiency data centres and cooling configurations that eliminate considerable leaks. ➢ Apply efficient server usage of different virtualisations dedicated to specific tasks. ➢ Support alternative storage systems such as cloud computing. ➢ Improve algorithms of software programs to minimise the tiem processes needed to retrieve searching information. ➢ Assess the effectiveness and efficiency of the application software and social media websites to save time and electricity. ➢ Strengthen printer output management to cut back operational footprints. ➢ Conversion to digital documents. ➢ Adoption of virtual classrooms. ➢ Adoption of video and web conferencing to reduce travel cost and pollution. ➢ Implement BYOD's (Bring Your Own Device) strategy.

Table 6-2: IT resource optimisation for green solution

6.3.3 E-waste disposal management

The majority of research participants indicated that environmental sustainability helps to establish excellent and functional relationships between knowledge, awareness and action in individuals and organisations. Becoming environmentally responsible assists individuals

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to adopt proper e-waste disposal management. The focus of this property is the capability of universities' own internal environmental impact. The analytic and descriptive codes that were developed suggest that recyclability, acquisition of product quality, compatibility, obsolescence and purchasing of eco-labelled products are significant factors for e-waste disposal management.

3 Theme	Main objective	Findings
E-waste disposal management	Implement practices of reducing, reusing and recycling electronic waste management, so as to benefit education, the local community and the country at large and to reduce the pressure on non-renewable resources as well as help reduce waste, space and pollution.	➢ Manage e-waste disposal through recycling programs such as: Recycle, re-use and reduce. ➢ Know the volume of discarded e-products and identify the sources of e-waste. ➢ Identify toxic materials of e-waste to reduce risk potentialities. ➢ Analyse products from cradle to grave phases. ➢ Assess the proper acquisition of products for depletion and degradation. ➢ Reclaim the resale values (residual value). ➢ Identify product longevity through strengthening and producing quality products ➢ Identify types of e-waste ➢ Arrange for safe collection centres, and take-back recycling programs to reduce landfills. ➢ Provide techno trashes (e-waste deployment centres). ➢ Identify safe means of transportation.

Table 6-3: E-waste disposal management

6.3.4 Energy efficiency and carbon footprint reduction

Energy efficiency and conservation, particularly involves three elements: saving energy, improving the use of energy and the reduction of carbon footprints. Rising energy consumption and electricity bills, rising concern over greenhouse gas and hazardous e-waste and the major funds needed to expand the current activity into environmental

sustainability transformation are dependent on sustainable green IT operations and practices.

4 Theme	Main objective	Findings
Energy efficiency and carbon footprint reduction	Enable role of eco-sustainability in reducing pollution of carbon footprint and energy consumption, in order to assist South African universities to conceptualise and measure their green IT readiness as well as to control and redesign low-carbon economy and clean energy activities.	➢ Explore alternative energy sources for energy efficiency (saving) and energy reduction (consumption). ➢ Investigate energy-saving practices (power management, altering lighting systems and safe mode. ➢ Replace energy-intensive computer equipment and peripherals with less energy-intensive devices. ➢ Invest in eco-labelled product certification, especially with respect to energy efficiency (energy star). ➢ Apply the reduction of carbon footprint techniques.

Table 6-4: Energy efficiency and carbon footprint reduction

6.3.5 Socio-economic relevance

The fifth regulating concept emerging from the inerviews was labelled as cost analysis benefit. The data demonstrates that environmental sustainability is managed and controlled by measuring its financial or economic value. Sustainability cannot be managed without optimising performance in the supply chain green procurement, and this has a material effect on any environmental sustainability transformation. This ensures that the manufacturing process of electronic devices has little or no negative effect on the environment.

5 Theme	Primary sources	Secondary sources
Cost benefit relevance	Determine what green business practices entail and examine the impact of the start-up cost in implementing rapid technology change that offers considerably under-powered (energy-saving) benefits for adopting green IT products, applications, services, policies and	➢ Reduce the cost of unnecessary resources. ➢ Promote quality service. ➢ Have an eco-labelled identity. ➢ Optimise market performance and competitiveness in supply chain. ➢ Marketing and communications teams to sell product sustainability.

	practices.

Table 6-5: Socio-economic relevance

6.4 Major findings

- ✓ Sustainable environment

- ✓ Increased optimisation in use of IT for eco-efficiency and the reduction of hazardous substances

- ✓ Improved e-waste deployment

- ✓ Reduction of carbon footprints, conservation of energy and natural resources

- ✓ Improved economy wise products

6.5 Limitations of the study

Although the major objectives of the study were attained, it has some limitations which should be noticed as opportunities for future researches. The study was limited to universities' IT specialists, green IT policy makers, computer science and IT technicians, computer science and IT lecturers, post-graduate students and green computing initiatives across five randomly selected conventional universities of South Africa because of financial constraints. Conducting similar case studies that involve different institutions may reveal new results of environmental protection. Therefore, conducting additional case studies across educational institutions and schools involving different level/grades will enable researchers to test the proposed theoretical framework and will encompass the proposed set of sustainable green IT practices by including more.

Some of the respondents involved in this field did not know about green IT at all, while others were raising arguments that they were busy, and as a result they did not have time to be interviewed verbally or to complete the given written-format interview. Additionally, indications of the study was largely based on the perception of the participants which may be subjective and has limited generalisability. Thus, a research finding that will be entirely valid in the way originally tested need to be widely conducted on two side settings.

Due to distance problems and financial constraints, more than 50 written interviews were sent across two randomly selected institutions; however, only five respondents replied to the sender with regrets and excuses. The rest and the majority (45), did not try to reply to

the message at all. Thus, none of the online sent interview questions were welcomed positively by respondents. To add to this, there were always clashes between interview appointments scheduled by the secretary and the targeted respondents because of the semester break, citing the reasons that some of them were on holiday and others were overseas for conferences. To compensate for instances like these the subject source of data evidence have to be collected from a quantitative approach as well.

6.6 Suggestions for further work

Compared to the other well-known research subjects, green IT in particular has never been discussed as broadly as others. However, minor studies have addressed the sustainable green IT practices at educational institutions. Roughly over the past two decades the push toward sustainable green IT is initiated. An increase in sustainability education and green jobs are also occurring within green IT. As a result, there is a growing demand for green computing education as well. Yet, compared to the studies done on greening companies, the study done on the academic institutions is quite an under-researched field. On that account, there should be more studies to enhance the practical performance in educational institutions.

Environmental sustainability is a multifaceted research area involving almost every subject and every human activity with the connotation of "green" (viz green awareness, green economy, green business, green energy, Green Building Initiative (GBI), green chemistry etc.). The term "green" is used as a synonym for environmentally sustainable. Even if the shorter term conveys a few meanings that environmental sustainability does not, this is a significant call to academics to explore further and certify the key terms that should be used to define environmentally sustainable. For instance, not green water but clean water, not green food but health food.

What is green, in context, typically needs to be elaborated clearly with the idea of Information Systems and Technology as well. Any environment-related problem in a research domain with nascent theory is also generating new terms like green Information Technology (green IT), sustainable Information Technology (sustainable IT), sustainable green Information Technology (sustainable green IT), green technology (green tech), green computing, green Information Systems (green IS), sustainable Information Communication and Technology (sustainable ICT) or Information Communication and Technology for sustainability (ICT for sustainability), environmental technology

(envirotech), clean technology (clean tech), Environmental Management Information Systems (EMIS) etc.). Hence, as these concepts increase in popularity, "green" has been a provoking word in perusing more green discoveries.

The results of the research provide an insight in creating a framework for measuring sustainable green IT practices in universities of South Africa. In terms of broader perspectives further researches are required that involve a wide variety of schools and tertiary education institutions in adopting a more holistic approach to education with the aim of creating a better world for this generation and next generations.

The design of computers and their sub-systems traditionally focus on the analysis of the relationships between technology performances, user affinity to newer technology or application requirements and cost benefits. However, nowadays, due to ecological destruction, resource depletion, atmospheric change and the energy price escalation, IT sectors are urged to analyse and to consider the environmental issue as new requirements in the development of IT solutions.

Based on these discoveries numerous future research opportunities can be suggested for a next step research agenda, namely:

1. This research highlighted the importance of environmental awareness for several reason (such as the conservation of irreplaceable natural resources that are vulnerable to the survival of the species) as an educational tool to help people understand the economic, aesthetic and biological importance of preserving resources. Further researches might be undertaken to help students and academic staff members understand the consequences of human activities on environmental impacts and identifies remedial solutions.

2. Exploring if energy consumption is one of the most significant contributors to the university's carbon emissions would be a primary concern. The majority of the interviewees reported that there is a variety of green practices that can be done to tune the higher institutions constantly from an energy and emissions standpoint, for instance, eliminating energy leaks, exploring alternative energy sources, altering energy-intensive products for IT assets to include eco-sustainability, managing green IT metrics quantitative analysis on how to save energy (doing testing meters) and power benchmarking techniques.

If it is assumed universities have bulky high-ended computers involved with gaming and social media activities, running with Windows 7 and left on 24/7. A typical personal computer uses 65 to 250 watts and LCD uses 20 to 40 watts.

We can calculate the energy consumption of a typical desktop with high energy hog (200 watts) running for 24/7 costs more before greening.

$$\frac{\text{Watts} \times \text{hours used}}{1000} \times \text{cost per kilowatt-hour} = \text{Total cost}$$

$$\frac{200 \times (24 \times 365)}{1000} \times R\,0.36 = \text{Total cost}$$

$$\frac{200 \times 8760}{1000} \times R\,0.36 = \text{Total cost}$$

$$\frac{1{,}752{,}000 \text{ watt-hour } (1{,}752 \text{ kWh})}{1000} \times R\,0.36 = \textbf{R 631}$$

While, if you are using a computer with a smaller less energy hog (100 watts) running for two hrs per day and five days per week the cost is less after greening.

$$\frac{\text{Watts} \times \text{hours used}}{1000} \times \text{cost per kilowatt-hour} = \text{Total cost}$$

$$\frac{100 \times (10 \times 52 \text{ weeks})}{1000} \times \text{cost per kilowatt-hour} = \text{Total cost}$$

$$\frac{100 \times 520}{1000} \times \text{cost per kilowatt-hour} = \text{Total cost}$$

$$\frac{52{,}000 \text{ watt-hour } (52 \text{ kWh})}{1000} \times R\,0.36 = \textbf{R 18.70}$$

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Based on this fundamental practical example, before greening assessment universities were paying R 631, while after greening implementation the price reduced to R18, 70 per year on per computer. If this measure is transferred to hundreds of computers used on campus, a huge amount of saving will be exposed.

It is imperative to do further quantitative research on how to save energy with testing and power benchmarking techniques to assess the energy consumption of the computer under different system run levels and energy-saving modes.

3. Conducting further work on future paperless transformation and efficiency could contribute much to environmental sustainability. Considering some of the environmental impacts when using paper, such as cutting trees that release oxygen, paper that goes into the waste stream, real time spend in the updating and delivery of the document, costs with paper and printers should encourage universities to evaluate their educational performance for greening, paperless and an eco-friendly environment. Besides, they will protect the environment by saving trees, and allow universities to be more productive by saving time and money with every record and transaction executed.

6.7 Recommendations for sustainable green IT practices

The improper use of technology affects the environment in some way or another. Knowingly or not, these choices affect the society directly or indirectly. Hence, it is imperative for students, academic staff members and social workers to implement green IT practices and to act responsibly and be more environment-friendly and caring.

Developing the truthful recommendations for measuring sustainable green IT practice requires in-depth knowledge of its current performance level, alternative use of technologies, its affordable costs and possible interdependencies with other systems and processes. There is no easy answer regarding sustainable green IT measurements. A life cycle analysis, from the process of production to the end of life is the only process that may give reliable answers to this question.

Students and staff members may perform well, provided that they are exposed and subjected to the knowledge of sustainable green IT practices; which could also assist other

higher education institutions in South Africa to renew themselves when faced with problems related to the environmental impact. Therefore, effective practice and good performance is directly related to the following recommendations:

6.7.1 Promote environment-related green IT awareness:

IT and other related departments in universities of South Africa can be a model to students and faculties to promote and encourage awareness and more knowledge about green IT practices. Green IT policy makers of the universities can support this by establishing a few green IT practices or policies for laboratories (compute LANs), lecture rooms and offices. In addition to this, students and faculties should have more practical experience and knowledge about green IT measures. Therefore, action should be taken to educate new generation about the danger of the climate change and global warming, for instance, an enforcement or empowerment of climate change educational act.

Some concepts that are suggested for recommendations to promote environment-related green IT awareness are:

- Assisting universities to adopt an eco-friendly responsible attitude, by launching an awareness of Environmental Management Information Systems and Technology (EMIS & T) or sustainable green IT all over campus to create knowledge, improve abilities, understanding, values, attitudes, and skills among students and staff members regarding the environmental stewardship.

- Transforming green IT practices across universities, by introducing a core subject, "green technology" or "green environmental technology" that encourages the awareness of environmental management and even creates an educational competitive advantage and research level in environment-related green IT practices.

- Requesting students and academic staff members to do practical experiments on how to save energy using testing meters and power benchmarking techniques to assess the energy consumption of the computer under different system-run levels and energy-saving modes.

- Allowing students to engage in diversity of research field, especially, in the areas of power optimization in compilers, computing systems or other areas where the research will be required employing the same power benchmarking techniques.

6.7.2 Enable optimisation of technology for eco-efficiency

The overall goal of green IT is quality assessment, innovation and continual improvement in the sustainable performance about computers and its sub-systems and of course, need to evaluate the companies that make them to consumer and other stakeholders. Thus, it is imperative for universities and other tertiary educations to operate within this listed below prescribed efficiency-requiring framework:

      i.   Are they made with fewer toxic constituents?

      ii.   Do they use recycled content? (Are they recyclable ?)

      iii.   Are they energy efficient (e.g., showing the "Energy Star" label)

      v.   Are they designed for easy upgrading or disassembly

      vi.   Are they taking minimal packaging?

      vii.   Do the suppliers of the equipment offer leasing or take back options?

      viii.   Have they been recognized by independent certification groups (such as the Swedish TCO or Blue Angel or others) as environmentally preferable?

Based on the above-mentioned efficiency-requiring framework, universities are requested to optimise their IT products for eco-efficiency. Remodelling the IT architecture that is currently used should demonstrate to be beneficial in the long term. Thus, IT users need to take into consideration of their optimised resource in line with sustainable green IT and eco-efficiency. Here below, a choice to utilise optimized and efficient green IT resource are proposed:

1. Promote green use in lessening the energy consumption of computers, data centres, and different ICT equipment. It also includes using them in a responsible way that will have no negative effect on the environment.

2. Implement green manufacturing to ensure the manufacturing process of electronic devices will have little or no negative effect on the environment, and the users will not be exposed to harmful substances; thus preventing occupational and health hazards.

3. Develop green design that ensures electronic devices are energy efficient and environmentally friendly. Being an affordable devoid of any concealed cost of waste and improved resource consumption with increased efficiency, and durability.

4. Practice energy-efficiency data centre and cooling configuration, to eliminate considerable amount of energy leaks.

5. Use efficient servers usage by virtualization dedicated to a specific task. These data servers must be efficiently used. One of the mechanisms is load balancing which chooses the optimum resource among many. Also by using virtual software to perform these tasks, a single server may be used to power these virtual servers, dramatically reducing energy consumption.

6. Support alternative storage methods. Storage drives are another main element of data centre infrastructure and, as universities storage needs increase; more energy is used to power these hard drives. It can be reduced by using large capacity drives and performing data centre audits to eliminate redundancies in the system.

7. Use thin clients that each user has a virtual desktop which includes a mouse, keyboard and screen while the remaining unit is shared by all at a central location.

8. Allow cloud computing services that include infrastructure, application, and storage space for a nominal fee and re-provisioning of resource, telecommuting and thereby increase profits.

9. Improve the algorithmic of software process to minimise the search results usually presented in list and are known as hits of the information.

10. Strengthen printer's output management. Centrally located printer may be used to handle all printing tasks virtually eliminating numerous machines being left on all day consuming energy and driving up costs. Thus, additional, guidelines for printing could be based on the following matters:

   - Not to print in colour in order to cut print cost unless they are strictly required.

   - Use a printer with a multifunction device that use four in one (printer, scanner, copier and fax) to save both energy and space.

- Refill computers cartridges because refilling computer ink cartridges are cheaper and more environmentally friendly.

- Buy recyclable and Chlorine free paper.

- Properly recycle waste paper to save materials that comes from renewable resource and use that are made from organic products, bamboo, cotton and hemp.

- Transform dynamic learning of students, instructors, administrators and educational activity through significantly increased engagement of paperless method such as:

    i. Exchange study materials, class notes and assignments over the Internet or portable storages to reduce print materials

    ii. Review and modify documents on the screen and use print preview instead of printing them out.

    iii. Use print in draft mode (print more screen pages to a paper page)

    iv. Use sharing systems or pop-up advertises in universities websites instead of printing advertises all over the corner of the campus.

    v. Keep copies of important emails, files and other important documents on your computer than printing several times on daily basis.

    vi. Use a printer that support double side copy to print on both side to promote paper cut.

    vii. Send email instead of faxes or send faxes directly from your computer to eliminate the need for a hard copy.

    viii. Enhancing e-statement, e-payment, e-education, to ensure students and lecturers are using effective and efficient, paperless way of tools during the period of study.

    ix. Utilise kiosk machine designed within a public exhibit that delivers access to information and applications for communication, business, entertainment, and education.

x. Encourage using cloud computing, telecommuting, web conferencing to reduce greenhouse gas emissions.

6.7.3 Responsible e-waste and u-waste disposal management

To know the volume of discarded e-products (computer, hardcopy devices, screens, keyboards, CPU, TVs, mobiles and peripherals) in South Africa, a routing of product reports are supposed to be done on a daily or yearly bases, whether it is in tone or units, to find out what happens to e-waste in the universities?

Some of the proposed recommendations for the resource depletion and degradation practices are:

1. Responsible disposal and recycling management:

   This is important because proper disposal potentially eliminates the threat of harmful toxins being released into the environment and allows for the re-use of equipment to reduce the amount of waste. These initiatives exhibit the requirement of going green. There are many open challenges in computing which are covered under this sub-section:

   - Establish campus-wide recycling programs for obsolete computers and consumer electronics equipment. In addition to that, a report of recovering and recycling should be done on three matters (R3 = recycle, re-use and reduce). These could be practical techniques for resource depletion methods. The recycling process, refurbishment and re-use of obsolete electronic devices are e-waste treatment processes. Disposing electronics through the correct channel reduces health risk possibilities. Besides, the failing to establish proper recycling programmes exploits precious natural resources that leads to waste of rare-earth minerals to manufacture electronics in time to come.

   - Dispose of e-waste according to federal or state and local regulations and policies so as not to affect the environment.

   - Provide containers into which computers and e-waste accessories such as glass, metals, plastics and paper can be thrown. Recycling helps to save precious energy (both renewable and non-renewable), time and money spent in manufacturing these electronic items. Likewise, resources used and

money spent in manufacturing an electronic item from scratch are far greater than those needed for recycling it.

- Not to dispose e-waste in the way that affects the health status of human beings and the environment. E-waste is full of toxic materials (methane, laughing gas) that can harm to the health of human beings and may lead to obesity, carpal tunnel syndrome, cancer, nerve damage and immune reactions in humans.

2. Analyse of products' life cycle environmental efficiency:

- A report on consumers stockpile electronic products to manage end-user-computing including equipment choice and energy-saving practice.

- A report on the amount of e-waste being produced, including mobile phones computers and other gadgets.

- A report on the generation of e-waste in landfill or incineration.

- A report on illegally traded or dumped products each year.

- A report on the dangers posed by e-waste (toxicity) dumping products to the effects on human.

3. Assessing the digital divide and the proper acquisition on ICT resources:

- Resource recovery from recycling electronics (residual value).

- Resources used in the manufacturing of electronics.

- The quantification of resources purchased and determining whether they are really needed with how and where they are being used.

4. The purchase products that are aimed at reducing the e-waste resources and that use minimal packaging must be given preference. Additionally, suppliers who offer a take-back or trade-in program must be sought out and given preference.

5. Supplies should be bought in bulk in order to minimize wastes from packaging as well as fossil fuel from transportation.

6. Donate old computers and other peripherals to reduce the rate of e-waste creation. Moreover, those who cannot afford to buy a computer can benefit from such

donations. Donation is also a remedy to keep e-waste from incineration and landfill.

6.7.4 Carbon footprint reduction and energy consumption

There are currently an unknown number of computers left active on various campuses for unidentified lengths of time. As the number of computers and users at universities increase, a green IT strategy needs to address the issue of energy consumption to raise a large-scale energy conservation on the following recommendations:

1. Explore alternative sources of energy that reduce power consumption in computer laboratories and personal computers across campus. The efficient resource utilization leads to efficient methods to evolve. With time renewable and natural energy sources are being used to power data centres, such as nuclear or hydroelectric power, solar energy etc. This saves money and generates fewer CO_2 emissions.

2. Investigate energy-saving techniques and switch to energy-saving modes: power management settings, unplugging adopters when not in use, unplugging battery chargers when charging is complete and setting computers to sleep mode after 15 minutes of inactivity is good choice to reduce IT energy consumption. Just running your computer eight hours a day only without any energy-saving modes cannot help save energy.

3. Replace equipment that are energy intensive, such as: laser printer versus inkjet or dot-matrix printers, cathode ray tube (CRT) monitors versus liquid crystal displays (LCD), desktop computers (868 KW) versus notebook computers (190 Kw) and so on.

4. Identify those who use green IT equipment as best-case scenario (for educational purpose) and those who don't as worst-case scenario (for social media tools like discussion boards, blogs, Facebook, and YouTube). However, it is not that easy, as the computing process consumes electricity as well.

5. Purchase technology designed to be eco-friendly which is recyclable, upgradable, long-lasting and has a potential for energy conservation.

6. Use energy-efficient light bulbs in offices and classrooms and build quality houses that do not affect the environment in terms of design and workmanship in

education, especially in allowing cool temperatures to ventilate across the buildings (offices, classrooms, laboratories and computer LANs).

6.7.5 Socio-economic relevance

As a result of growing concerns related to environmental impact the energy efficiency, natural resources depletion and measuring the carbon footprint of the electronic products, is a factor in decision making for universities and impacts competitiveness. Organisations are more interested in sustainable production, as well as in the undertaking of corporate social responsibility (CSR) initiatives. Choosing a product or service supplier is no longer based on the price of the product or service only, but also on its environmental impact. Sustainability in organisations has still a long way to go. Many green organisations severely depend on buying offsets to reduce their carbon footprints. Leading organisations are implementing innovative solutions that reduce their utility costs and "green" their procurement practices. Due to these reasons, there are considerable economic motivations for universities to take control of their own business area in order to have competitive advantages:

- funding from government and non-governmental organisations to invest in green initiatives (renewable energy, smart grids, energy efficiency, etc.)

- purchasing products that are accredited to meet eco-labelling product certification in order to help advance sustainability criteria within the sector.

- Realising competitive advantages through environment-friendly technologies.

6.8 Conclusion to the study

Chapter 6 is the research conclusions based on all the fore-going chapters in the study. In this chapter, the research problem was addressed, the research questions were answered, and the research objective was achieved (section 1.5), by verifying an empirical framework for measuring sustainable green IT practices. Furthermore, Chapter 6 presented practical guidelines and recommendations for universities in South Africa which are applicable to other educational areas such as schools, institutions and colleges.

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APPENDICES:

APPENDIX 1: Certificate of Ph.D. colloquium and publication generated from the research process

1.1 Proposal

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

Faculty of Commerce and Administration

Private Bag X2046, Mmabatho
South Africa, 2735
Tel: 018-389 2554 Fax: 018-389 2090
Web: www.nwu.ac.za

FHDRC5/2011

DOCTORAL COLLOQUIUM

The members of the colloquium appointed to attend the presentation of

_____ G E Woldu _____ on _____ 31 October 2013 _____

find it satisfactory and recommend that it be approved.

Type of presentation: _____ Proposal _____

Approval: --

Accepted   Recommendations   Referred back

[✓]

---------------------------------- Prof T Pelser
Director of the Graduate School of
Business and GovernmentLeadership
Member of FHDRC

---------------------------------- Prof J Mukuddem-Petersen
Professor at the Graduate School of
Business and Government Leadership
Member of FHDRC

---------------------------------- Prof M Petersen
Research Professor of the Faculty
Of Commerce and Administration
Member of FHDRC

Colloquium approval 31 June 2013

1.2 Literature review and methodology

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

Faculty of Commerce and Administration
Private Bag X2046, Mmabatho
South Africa, 2735
Tel: 018-3892554 Fax 018-3892090

FHDRC 5/2014

PHD COLLOQUIUM

The members of the colloquium appointed to attend the presentation of

G E Woldu

on *28 October 2014* find it satisfactory and recommend that

it be approved.

Type of presentation: *Literature review and Methodology*

Approval: *Approved*

Prof H Eita
School of Economics and Decision
Sciences
Chairperson of the FHDRC

Prof N Mavetera
Director: School of Economics and
Decision Sciences
Member of FHDRC

Prof S Swanepoel
Executive Dean of FCA
Member of FHDRC

Colloquium approval letter

1.3 Presentation of research findings

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

Faculty of Commerce and Administration
Private Bag X2046, Mmabatho
South Africa, 2735
Tel: 018-3892554 Fax 018-3892090

FHDRC 5/2015

PHD COLLOQUIUM
(Ghebre)

The members of the colloquium appointed to attend the presentation of

Mr Ghebre Embaye

on _13 October 2015_ find it satisfactory and recommend that it be approved.

Type of presentation: _Findings_

Approval: _Approved_

(signature)

Prof N Mavetera
Professor in School of Economics and
Decision Sciences
Member of the FHDRC

(signature)

Prof J B van Lill
Director: School of Management
Sciences
Member of the FHDRC

(signature)

Prof J Meyer
Director: Graduate School of Business
and Government Leadership
Member of the FHDRC

Colloquium approval letter

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1.4 Certificate of international academic journal

INTERNATIONAL
JOURNAL
OF ARTS AND SCIENCES

Certificate of Excellence

Mr. Ghebre Embaye Woldu

Is awarded this certificate in recognition of

RESEARCH PRESENTATION AT MULTIDISCIPLINARY CONFERENCE

At FHWien University of Applied Sciences of WKW, Vienna

19 to 23 April 2015
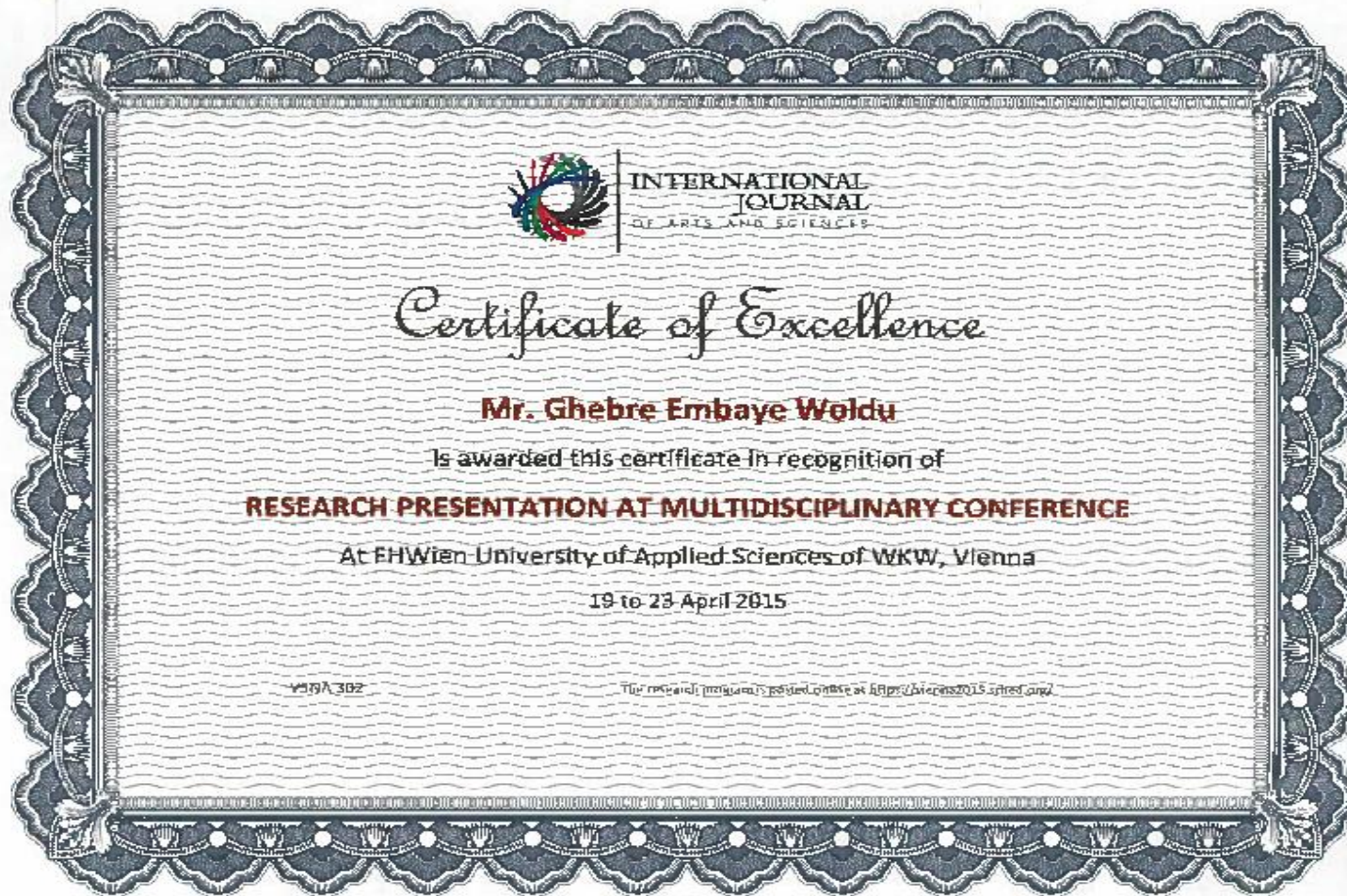
APPENDIX 2: Certificate of language editing

CliffSmuts Language Practitioner/Taalpraktisyn

27 Stamper Street
WOLSELEY
68320
Tel. 023 231 0025
Mobile: 084 679 2210
Email: csmuts@xsinet.co.za

24 February 2016

STATEMENT OF EDIT

I, Cliff Smuts, hereby declare that I edited the language of the thesis

A Framework for measuring sustainable green Information Technology practices in universities of South Africa by Mr Ghebre Embaye Woldu.

On completion of the edit I gave the author certain instructions on certain aspects and issues he had to heed to/change in order for the language to be fine. If that is done correctly I deem the language to be clear, understandable and on standard.

I also cross-checked references and edited the reference style, once again with certain instructions to the author to complete and correct certain entries. If that is done, all sources used during the research are entered in the References, and the referencing style is in line with the style guide used by the institution where Mr Woldu is enrolled for this PhD studies.

Thank you.

C.B. Smuts
(Member of:
the South African Translators Institute,
the Professional editors' Guild
and ProLingua)

APPENDIX 3: Solemn declaration

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

Academic Administration (Mafikeng Campus)
SOLEMN DECLARATION (for Masters and Doctoral Candidates)

1 Solemn declaration by student

I _G.E WODSU_ declare herewith that the mini-dissertation/dissertation/thesis entitled,
A Framework for Measuring Sustainable green IT practices in University of South Af
which I herewith submit to the North-West University as completion/partial completion of the
requirements set for the _PHD_ degree, is my own work and has not already been submitted to
any other university.

I understand and accept that the copies that are submitted for examination are the property of the
University.

Signature of candidate _____ University-number _247 567 2 5_

Signed at _Mafikeng_ this _20_ day of _November_ 20_15_.

Declared before me on this _20_ day of _NOVEMBER_ 2015

Commission...

2 Declaration by supervisor/promoter

The undersigned declares:

2.1 that the candidate attended an approved module of study for the relevant qualification and that
the work for the course has been completed or that work approved by the Senate has been
done

2.2 the candidate is hereby granted permission to submit his/her mini-dissertation/dissertation or
thesis

2.3 that registration/change of the title has been approved.

2.4 that the appointment/change of examiners has been finalised and

2.5 that all the procedures have been followed according to the Manual for post graduate studies.

Signature of Supervisor: _____ Date: _20/11/2015_

Signature of School-Director: _____ Date: _17/12/15._

Signature of Dean: _____ Date: _05/04/16_

APPENDIX 4: Ethical clearance approval

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
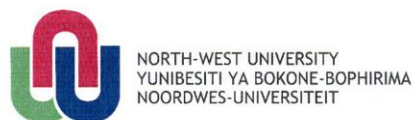
Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Ethics Committee
Tel   +27 18 299 4849
Email Ethics@nwu.ac.za

ETHICS APPROVAL OF PROJECT

The North-West University Research Ethics Regulatory Committee (NWU-RERC) hereby approves your project as indicated below. This implies that the NWU-RERC grants its permission that provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: A framework for measuring sustainable green information technology practices in universities of South Africa	
Project Leader: Prof N Mavetera & Prof S Lubbe **Student:** GE Woldu	
Ethics number:	N W U - 0 0 2 2 7 - 1 4 - A 9 Institution Project Number Year Status Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation
Approval date: 2014-10-27	**Expiry date**: 2019-10-26

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-RERC:*
  - *annually (or as otherwise requested) on the progress of the project,*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-RERC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-RERC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-RERC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-RERC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof Amanda Lourens
Chair NWU Research Ethics Regulatory Committee (RERC)

APPENDIX 5: Table of construction for interview

4.1 Focus group agenda

Agenda item description	Duration
Pre-session preparation (researcher does preparation)	
✓ Set out seating, name cards, water and drinking glasses, sweets and muffins, pens and notepads. ✓ Set up and test recording device. ✓ Hand out hard copies of framework (as already sent out on the invitations) and informed consent forms.	
Introduction (session begins – moderator runs introduction)	10 min.
✓ Greet all participants in session and thank them for participating. ✓ Request cell phones to be put on silent and only urgent calls to be taken. ✓ Introduce the researcher and moderator and summarise their roles. ✓ Present the research goals for the session. ✓ Ensure confidentiality and anonymity of the resulting data by the researcher. ✓ Ask permission to audio-record session for ease of analysis, instead of note-taking. ✓ Obtain informed consent forms. ✓ Present the format of the session. ✓ Present the rules of the session (one person to speak at a time due to transcribing difficulties, open session/debate, everyone's views are important, there are no right or wrong answers, please respect all comments from other participants, adhere to the time limits for each research question, and that a report of the findings will be given to each participant after analysis). ✓ Allow each person to briefly introduce themselves (first name and involvement in sustainability only, to avoid any dominance by way of titles).	
Discussions topics	**35 min.**
1. Demographic	1 min.
1.1. Would you please tell me a little about yourself – your age, gender and occupation and as well as how long you have been working in your organisation? (These questions are for identification only.)	
2. General concept about sustainable green IT	7 min.
2.1. Where and when did you hear about green information technology? 2.2. Why is green IT important to you?	

2.3. What role of initiatives and motivations should universities, government authorities and even individuals play over all green IT strategy to promote a sustainable environment?

2.4. How can a university develop sustainable green IT ethics and a national recognition policy to promote green jobs towards sustainable products and resources?

3. **E-waste and u-waste management)**	6 min.

3.1. Once the university has received the new computers and other IT-related equipment what should the university do with the obsolete computers?

3.2. What do you think should the scenarios of the universities be for buying an eco-friendly range of products that are aimed at reducing the e-waste generation and conserving resource?

3.3. What are the possible reasons for discarding the old computers and IT equipment at your organisation? (Hint: faulty or damaged, power failure, compatibility-software issue and affinity to newer technology)

4. **Energy power management:**	8 min.

Power assessment

4.1.1. How may green IT policy makers play a significant role in helping the university to reduce IT power consumption and advocate the use of green technology in improving energy efficiency?

4.1.2. What other alternative approaches of improving energy efficiency techniques (i.e. renewable energy) and means of energy or power saving practices could universities substantially have to reduce both their operational costs and IT power consumption within their business?

Footprint assessment

4.2.1. What measures should IT leaders implement in pursuing green IT resources and systems operations to reduce a total carbon footprint of a business against the intensive carbon emission and energy consumptions?

5. **Green information technology (green IT) for hardware and software optimisation**	4 min.

5.1. What new green IT resources and systems should be used in transforming the current use of IT resources and systems operations to make green much better?

5.2. What approaches and methods of green IT practices should be adopted and implemented in a university to create dynamic learning experiences and ways to reduce environmental pollution, impact, carbon footprint and degradation?

6. **Socio-economic relevance**	8 min.

6.1. How will the adoption of green IT affect the start-up cost to the university in view of rapid technology change and the fact that green IT is designed to use considerably less

power and create a sustainable environment?

6.2. How will green IT improve the environmental management capabilities and streamline business processes to make the university both greener and profitable?

6.3. How can the readiness of green IT at the university be measured and explained?

6.4. Is there anything else you would like to add about green IT before we close?

Thank you for all that valuable information.

| **Ending the session (session ends – moderator runs ending session)** | 1 min. |

- Thank the participants for participating.
- Reiterate that a report of the findings will be given to each participant after analysis.

"When one tugs at a single thing in nature, he finds it attached to the rest of the world."

John Muir

4.2 Data-gathering interview guide

A FRAMEWORK FOR MEASURING SUSTAINABLE GREEN IT PRACTICES IN UNIVERSITIES OF SOUTH AFRICA

For office use only: Respondent code: _____

VOLUNTARY INTERVIEWS FOR:

- Universities' IT specialists,
- Computer and IT technicians
- Computer Science and IT lecturers and post-graduate students
- Green IT policy makers and green computing initiatives.

"The longer we wait to respond, the more the risks of impact will have happened to the environment. Contrary-wise, the sooner we take action, the more options we will have to reduce risk."

Researcher: Ghebre Embaye Woldu (072 1857685)

Promoter: Professor Nehemiah Mavetera

Co-promoter: Professor Sam Lubbe

Faculty of Commerce and Administration

North-West University

Note to respondents:

NB: We would like to request only 30 to 35 minutes of your time to interview questions. What you say in this interview will remain private and confidential. No one will be able to trace your feedback and opinions back to you as a person in any means. You are most welcome to skip any question that you are not comfortable with and to ask questions that may seem unclear to you.

Discussion title (approximately 30 to 35 minutes)

1.   Demographic   (1 min.)

1.1. Would you please tell me a little about yourself – your age, gender and occupation as well as how long you have been working in your organisation? (These questions are for identification only).

2.   General concept about sustainable green IT   (7 min.)

2.1. Where and when did you hear about green IT?

2.2. Why is green IT important to you?

2.3. What role of initiatives and motivations should universities, government authorities and even individuals play over all green IT strategy to promote a sustainable environment?

2.4. How can a university develop sustainable green IT ethics or national recognition policies and practices to promote green jobs towards sustainable products and resources?

3. E-waste and u-waste management) (6 min.)

3.1. Once the university has received the new computers and other IT related equipment, what should the university do with the obsolete computers?

_____

_____

_____

_____

_____

3.2. What do you think should the scenarios of the universities be for buying an eco-friendly range of products that are aimed at reducing the e-waste generation and conserving resources and energy?

_____

_____

_____

_____

_____

3.3. What are the possible reasons for discarding the old computers and IT equipment at your organisation? (Hint: faulty or damaged, power failure, compatibility software issue and affinity to newer technology)

_____

_____

_____

_____

_____

4. Energy power management (8 min.)

Power assessment

4.1.1. How may green IT policy makers play a significant role in helping the university to reduce IT power consumption and advocate the use of green technology in improving energy efficiency?

_____

_____

_____

_____

_____

4.1.2. What other alternative approaches of improving energy efficiency techniques (i.e. renewable energy) and means of energy or power saving practices could universities substantially have to reduce both their operational costs and IT power consumption with in their business?

_____

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_____

_____

Footprint assessment

4.2.1. What measures should IT leaders implement in pursuing green IT resources and systems operations to reduce the total carbon footprint of a business against the intensive carbon emission and energy consumptions?

_____

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_____

_____

_____

5. Green Information Technology (green IT) for hardware and software optimisation   (4 min.)

5.1. What new green IT resources and systems should be used in transforming the current use of IT resources and systems operations to make them greener?

_____

_____

_____

_____

_____

5.2. What approaches and methods of green IT practices should be adopted and implemented in a university to create dynamic learning experiences and ways to reduce environmental pollution, impact, carbon footprint and degradation?

_____

_____

_____

_____

_____

6. Socio-economic relevance   (8 min.)

6.1. How will the adoption of green IT affect the start-up cost to the university in view of rapid technology change and the fact that green IT is designed to use considerably less power and create a sustainable environment?

_____

_____

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6.2. How will green IT improve the environmental management capabilities and streamline business processes to make the university both greener and profitable?

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6.3. How can the readiness of green IT at a university be measured and explained?

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6.4. Is there anything else you'd like to add about green IT before we close?

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Thank you for all that valuable information.

APPENDIX 6: Full list of interview radio recording (on CD)
APPENDIX 7: Full list of interview transcripts (on CD)
APPENDIX 8: List of incidents and codes for all the interviews (on CD)
APPENDIX 9: Network diagram (on CD)

APPENDIX 7: A spreadsheet-based concept-centric literature matrix

#	Author/s, Year, Publication	Total per reference	1 Environmental sustainability	2 E-waste and u-waste management	3 Optimisation of IT resources for green growth	4 Energy-efficiency and energy conservation	5 Socio-economic relevance
	Total per concept						
1.	14th Annual IEEE/ACM International Symposium (2014)				X	X	
2.	Adamson, Hamilton, Hutchison, Kazmierowski, Lau, Madesjki *et al.* (2005)						
3.	Aggarwal, Goswami and Nath (2013)				X		
4.	Ahmad, Nordin and Bello (2013)		X		X		
5.	Albertson (2008)			X			
6.	Anderegg, Prall, Harold and Schneider (2010)		X				
7.	Appasami and Suresh (2011)				X		
8.	Apple Company (2014)				X		
9.	Auerbach (2010)		X				
10.	Avelar (2011)				X		
11.	Bandyopadhyay (2008)			X			
12.	Beatley and Manning (1998)		X		X		
13.	Begon, Townsend and Harper (2006)		X				
14.	Bellamy (2013)		X				
15.	Benitez-Amado and Walczuch (2011)		X				
16.	Bose and Luo (2011)				X		
17.	Boston Consulting Group (2013)					X	
18.	Bray (2006)				X		
19.	British Geological Survey (n.d.)					X	
20.	Brunoro (2008)						X
21.	Business-as-usual (BAU, 2012)					X	
22.	Carnagie, Lewon and Shomali (2008)		X				
23.	Carvalho (2011)					X	
24.	Chen, Boudreau and Watson (2008)			X			
25.	Chevron Company (2011)		X			X	
26.	Chevron Company (2012)		X			X	
27.	Chitnis, Bhaskaran and Biswas (2011)				X		
28.	Coleman (2014)		X				
29.	Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2011)		X				
30.	Conn (2011)		X		X		
31.	Coroama and Hilty (2009)				X	X	
32.	Dayson (2014)		X				
33.	Delphi Display Systems (2008)				X		
34.	Diedrich, Upham, Levidow and Van den Hove (2011)		X		X		

#	Author/s, Year, Publication	Total per reference	Environmental sustainability (1)	E-waste and u-waste management (2)	Optimisation of IT resources for green growth (3)	Energy-efficiency and energy conservation (4)	Socio-economic relevance (5)
	Total per concept						
35.	Diesendorf (1999)		X		X		
36.	Eberhard (2012)					X	
37.	Ekins, Simon, Deutsch, Folke and De Groot (2003)		X				
38.	Electronic Product Environmental Assessment Tool (EPEAT, 2014)						X
39.	Energy Information Agency (EIA) (2013)					X	
40.	EPA (2001)					X	
41.	EPA (2007)					X	
42.	EPA (2010)					X	
43.	EPA (2011)		X			X	
44.	EPA (2012a)		X				
45.	EPA (2012b)		X				
46.	EPA (2013a)		X				
47.	EPA (2013b)			X			
48.	EPA (2013c)					X	
49.	EPA (2013d)					X	
50.	EPA (2014)			X			
51.	European Commission (2009)		X			X	
52.	European Commission (2011)		X			X	
53.	European Commission (2013)		X				
54.	FAO (2008)		X				
55.	Finlay and Liechti (2008)			X			
56.	Fuchs (2008)		X	X			
57.	Geological Society of America (GSA) (006)		X				
58.	Gibson (2008)				X		
59.	Gingichashvili (2007)				X		
60.	Green Growth and Sustainable Development Forum (GG-SD) (2012)		X				
61.	Green Paper (1996)		X		X		
62.	Guardian (2013)			X			
63.	Halfman and O'Neill (2009)		X	X			
64.	Hamilton (2003)				X		
65.	Harris (2012)				X		
66.	Hassol (2002)		X				
67.	Herrmann, Gama and Helman (2012)					X	
68.	Herzog and Golomb (2004)					X	
69.	Horowitz (2003)				X		
70.	Howard (2014)				X		
71.	Hunsen (2008)		X				

#	Author/s, Year, Publication	Total per reference	1 Environmental sustainability	2 E-waste and u-waste management	3 Optimisation of IT resources for green growth	4 Energy-efficiency and energy conservation	5 Socio-economic relevance
	Total per concept						
72.	Intergovernmental Panel on Climate Change (IPCC) (2007a)		X			X	
73.	Intergovernmental Panel on Climate Change (IPCC, 2007b)		X			X	
74.	International Council on Clean Transportation (ICCT) (2011)		X			X	
75.	International Energy Agency (IEA) (2007)					X	
76.	Japan External Trade Organisatin (JETRO) (2012)				X		
77.	Jenkin, Webster and McShane (2011)		X		X		
78.	Jones (2009)			X			
79.	Kanellos (2009)				X		
80.	Karin (2008)					X	
81.	King (2013)		X				
82.	Kiruthiga and Kumar (2014)				X		
83.	Knorr and Gruman (2008)				X		
84.	Knutson (2008)		X				
85.	Kohli (2013)		X		X		
86.	Kumar (2011)			X			
87.	Kundra (2011)				X		
88.	Kyoto Protocol (1997)		X				
89.	Laine (2010)		X		X		
90.	Lamb (2009)				X		
91.	LaMonica (2011)					X	
92.	Lee, Chang and Fan (2004)				X		
93.	Lloyd-Smith and Immig (2011)			X			
94.	Lott (2012)		X				
95.	Madeira and Erin (2008)		X				
96.	McCabe (2009)				X		X
97.	McClure (2004)		X	X			
98.	McKinsey (2011)					X	
99.	Mell and Grance (2011)				X		
100.	Melville (2010)				X		X
101.	Mertens (1998)						X
102.	Midrar Ul Haq and Memon (2005)		X	X			
103.	Mill (2013)		X	X		X	
104.	Minn (2008)				X		
105.	Molla (2009)		X	X	X	X	
106.	Molla and Abareshi (2012)		X	X	X		X
107.	Molla, Pittayachawan, Corbit and Deng (2009)		X	X	X	X	X
108.	Mortimor (1999)				X		

#	Identifier	Total per reference	1 Environmental sustainability	2 E-waste and u-waste management	3 Optimisation of IT resources for green growth	4 Energy-efficiency and energy conservation	5 Socio-economic relevance
	Concepts						
	Author/s, Year, Publication						
	Total per concept						
109.	Murugesan (2008)		X	X	X	X	X
110.	Murugesan (2010)		X	X	X	X	X
111.	Murugesan (2013)		X	X	X	X	X
112.	Namias (2013)			X			
113.	National Academies of Science (2005)		X				
114.	National Aeronautics and Space Administration (NASA) (2013)		X				
115.	National Research Council (2008)		X				
116.	National Research Council (2011)		X				
117.	Natural Resources Defence Council (NRDC) (2012)		X				
118.	O'Connor & Meil (2012)			X			
119.	OECD (2011)		X		X		
120.	Oreskes (2004)		X				
121.	Otto, Monchuk and Jintanakul (2007)		X				
122.	Petzer, McGibbon and Brown (2011)						
123.	Pillai (2012)				X		
124.	Pitt, Parent, Junglas, Chan and Spyropoulou (2011)		X				
125.	Plambeck and Wang (2009)			X			
126.	Ponnavaiko (2013)				X	X	
127.	Ponte (2013)				X		
128.	Porter & Kramer (2006)				X		
129.	Queen Margaret University (2009)					X	
130.	Radiation and Nuclear Safety (2009)		X	X		X	
131.	Rainey (2006)		X				
132.	Rowe (2011)				X		
133.	Sabha (2011)			X			
134.	Samson (2007)				X		
135.	Smith (2013)					X	
136.	Socolow and Pacala (2006)				X	X	
137.	Steigerwald and Agrwal (2011)				X		
138.	Swaminathan (2013)			X			
139.	TCO Development (2012)						X
140.	The Editors (2009)					X	
141.	Thomas (2014)				X		
142.	Thomson and Van Belle (2014)				X		
143.	Toomey (2008)				X		
144.	Uddin and Rahman (2012)				X	X	
145.	UN-Climate Change (2013)		X				

Identifier		1	2	3	4	5
Concepts Author/s, Year, Publication	Total per reference	Environmental sustainability	E-waste and u-waste management	Optimisation of IT resources for green growth	Energy-efficiency and energy conservation	Socio-economic relevance
# Total per concept						
146. United Nations Environmental Programme (UNEP) (2008)		X	X			
147. United Nations Environmental Programme (UNEP) (2010)			X			
148. United Nations Environmental Programme (UNEP) (2011)			X			
149. University of Illinois (2009)			X			
150. Vanhorn (2005)				X		
151. Verdiem Corporation (2008)						X
152. Vesilind, Heine and Hendy (2006)		X				
153. Viswanathan (2011)				X		
154. Watson, Boudreau, and Chen (2010)		X				
155. Watson, Boudreau, Chen and Huber (2008)				X		
156. Weart (2011)		X				
157. Weems (2010)				X		
158. Wide Area Monitoring Information System (WAMIS) (2012)		X		X		
159. Williams (2013)				X		
160. World Commission on Environment and Development (WCED) (1987)		X				
161. WWF Global (2012)		X				

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