AN APPLICATION OF SOFT SYSTEMS METHODOLOGY ON A HOLISTIC LEVEL: RECOMMENDATIONS FOR DEVELOPING AND IMPLEMENTING GREEN ICT STRATEGIES IN NEW ZEALAND

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PREFACE AND ACKNOWLEDGEMENT

Through my research, three models have been developed to explore implications of Green ICT. In the level 3 model, a holistic view into these issues has been provided. I have adopted a systems approach, known as Soft Systems Methodology (SSM) to learn about the situation and develop recommendations for stakeholders to help them develop stakeholder-specific solutions. I also have taken the application of SSM a step further to a more holistic scope – within an interconnected group of stakeholders who have a common concern about an issue, instead of within a physical organization. Hopefully, this will provide new perspectives and new ways of thinking about the application of SSM.

“Rome was not built in a day”, and nor was this thesis. Besides my own hard work, during the year, the achievement has been essentially profited from some other people. Their wisdom and kindnesses have contributed to the completion of this work. Therefore, they must be acknowledged.

Firstly, I would like to give my biggest acknowledgement and respect to my principal supervisor, Professor Dr. Kay Fielden. Instead of providing me with many specific ideas about my research, her guidance is targeting a philosophical level on research methods – showing me where the “door” is and encouraging me to find it and walk through it by myself. Thus, I can feel that my self-study ability has been improved dramatically through working with her. She has also provided me with the strong positive energy on conquering various difficulties. For instance, in order to help me overcome my stammer, she has helped and encouraged me to give presentations at Unitec’s Research Symposium and the SIGGreen Workshop, thus my stammer has been improved and I have become much more confident than before. In addition, she is always encouraging me to release the passion on my interests and on pursuing the goal of my life. For any of my anti-conventional ideas, there is always a “Yes, you can do it by ...” from her, rather than denying these ideas and blocking my creative thinking ability. In all, I think she is a very excellent teacher and guider for students.

Secondly, I would like to thank my ex-associate supervisor, Associate Professor Dr. Donald Joyce. In contrasted with the help on a philosophical level provided by Professor Kay Fielden, he has taught me many practical techniques about doing research, such as survey techniques, sampling, ethical issues, writing style, and referencing techniques. He has often sent me new literature, which is related to my topic and gave advice regarding publishing papers.

Thirdly, I wish to thank Dr David Hawkins for providing me his ideas about Computing and the environment. In the beginning of my thesis, I did not have much idea about the
topic. He gave me many good ideas and suggested two books for me to read, and that really helped me to start.

Fourthly, I would like to thank the New Zealand government, the New Zealand green political group ICT spokesperson, the institution IT manager, the ICT leasing company manager, and the ICT scholar for supporting my research and completing the survey. They are the five participants of my research. Due to confidentiality, I am not going to mention their names.

I would also like to thank my parents. Without their hard working and financial support, it was impossible for me to complete my Masters study. Moreover, my girlfriend, she is with me almost every minute through online chatting, encouraging and reminding me about my life well-being and study, even if she is not being with me physically. Xi, I love you, more than words could ever express.

Furthermore, I would like to thank all the staff at Unitec post-graduate academic administration, especially Ms Cynthia Almeida. I am grateful for their help and support in providing me useful information about doing a Master thesis whenever I need. I would also like to thank the career consultant at Unitec – Yolanda Van Den Bemd. She has discovered two critical errors in my abstract and given me suggestions regarding possible solutions. Cathy O’Brien and Fran Skilton are two staff at Unitec Library who I would like to acknowledge. They have provided me with lots of help on the use of EndNote and helped me solve some tricky referencing problems associated with EndNote.

In addition, I wish to thank my schoolmates Raymond Lutui and Sotharith Tauch for their recommendations on the format of this thesis, and Ning Wei, ShivRaj Singh Virk, and Mohib Shah. We often get together and discuss our research. Plenty of ideas have been produced from our discussions and this has contributed to the completion of my thesis.

At the end, special thanks to Dr Logan Muller. Through conducting this research, his foresight about Green ICT has been proven, which he pointed out to me two years ago, the significance and popularity this area would gain, as well as the rich opportunities I would have in the industry in the future as a Green ICT professional.

Auckland, August 2011

Bing Qian ZHANG
ABSTRACT

This thesis has been conducted in order to identify and explore the issues involved in the development and implementation of Green ICT strategies in ICT recycling in New Zealand. There were interactions with five stakeholders – the New Zealand government, a green organization, an ICT leasing company, an ICT scholar, and an IT manager, to develop recommendations for “systemically desirable” and “culturally feasible” solutions by adopting systems approaches. Soft Systems Methodology (SSM) is applied to this research. Three levels of models that represent the real world situation have been built based on the information derived from a comprehensive literature review on Green ICT related issues. A survey was conducted with five relevant stakeholders and then the data was used to construct five conceptual models. A mapping of the real world (level 3 holistic model) was then constructed. Then five conceptual models were derived from the data. These models have been summarised into a table in the data analysis chapter. At the end of the thesis, a list of recommendations is presented based on the mapping results in the “Three Analyses” of SSM about the situation. The solutions derived then form the basis upon which recommendations for this research are presented that is both systemically desirable and culturally feasible.

This research indicates that the impact of ICT on a “green” manner is highly complex and far-reaching across technology, society, economy, education, politics, academics, and the environment. Therefore, for this case, the development and implementation of Green ICT strategies has been conducted with consideration given to the issues on a holistic level with cooperation of other sectors, as such the government, “green” organizations, industry associations, academics, and external service providers.

Furthermore, SSM has been further applied and tailored in a more holistic level, which is higher than a concept of an “organization” or “corporation” which commonly SSM addresses – within collection of interconnected group of stakeholders who have a common concern on a same issue, instead of within a physical organization.
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# GLOSSARY

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<td><strong>“Three Analyses” of SSM</strong></td>
<td>The “Three Analyses” of SSM includes analysis of intervention, social systems analysis and political systems analysis.</td>
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<td><strong>Anti-realism</strong></td>
<td>In analytic philosophy, the term anti-realism is used to describe any position involving either the denial of an objective reality of entities of a certain type or the denial that verification-transcendent statements about a type of entity are either true or false.</td>
</tr>
<tr>
<td><strong>Biota</strong></td>
<td>Biota is the total collection of organisms of a geographic region or a time period, from local geographic scales and instantaneous temporal scales all the way up to whole-planet and whole-timescale spatiotemporal scales.</td>
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<tr>
<td><strong>Building management system (BMS)</strong></td>
<td>Building management system: used in smart buildings to automatically control and adjust heating, cooling, lighting and energy use.</td>
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<td><strong>Carbon credit</strong></td>
<td>A carbon credit is a generic term for any tradable certificate or permit representing the right to emit one tonne of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO$_2$e) to one tonne of carbon dioxide.</td>
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<tr>
<td><strong>Carbon footprint</strong></td>
<td>Impact of human activities on the environment measured in terms of GHG produced, measured in CO$_2$e (CO$_2$ equivalent).</td>
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<td><strong>CATWOE</strong></td>
<td>A CATWOE analysis is a systems thinking tool of SSM to prepare comprehensive root definition models. It is the acronym for Clients, Actors, Weltanschauung, Owners, and Environment. Applying the CATWOE systems thinking tools places focus on the existing system or processes that take place within an organization and entails studying how the features of elements within the system or process interact externally and internally.</td>
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<tr>
<td><strong>Cloud computing</strong></td>
<td>Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.</td>
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<tr>
<td><strong>CO$_2$e</strong></td>
<td>Carbon dioxide equivalent.</td>
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<td>CRM</td>
<td>Customer Relationship Management (CRM) is a widely implemented strategy for managing a company’s interactions with customers, clients and sales prospects. It involves using technology to organize, automate, and synchronize business processes — principally sales activities, but also those for marketing, customer service, and technical support.</td>
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<tr>
<td>Data centre</td>
<td>Facility used to house computer systems and associated components.</td>
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<tr>
<td>Dematerialisation</td>
<td>The substitution of high carbon activities or products with low carbon alternatives</td>
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<tr>
<td>DSM</td>
<td>Demand side management</td>
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<tr>
<td>E-commerce</td>
<td>(Also known as electronic commerce): Buying and selling of products and services over the internet and other computer networks.</td>
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<tr>
<td>E-education</td>
<td>Commonly referred to as online education, e-education is the process of learning online.</td>
</tr>
<tr>
<td>E-government</td>
<td>‘E-government' (or Digital Government) is the utilization of the Internet and the world-wide-web for delivering government information and services to the citizens.</td>
</tr>
<tr>
<td>E-waste</td>
<td>E-waste (electronic waste) describes loosely discarded, surplus, obsolete, or broken electrical or electronic devices. Informal processing of electronic waste in developing countries causes serious health and pollution problems.</td>
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<tr>
<td>Flame retardants</td>
<td>Flame retardants are chemicals used in thermoplastics, thermosets, textiles and coatings that inhibit or resist the spread of fire.</td>
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<tr>
<td>Geographic information system (GIS)</td>
<td>System for capturing, storing, analysing, managing and presenting data and associated attributes that are spatially referenced to Earth</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication systems global system for mobile communications (GSM).</td>
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<td>Green ICT</td>
<td>“Green ICTs” is an umbrella term for ICTs with better environmental performance than previous generations (direct impacts) and ICTs that can be used to improve environmental performance throughout the economy and society (enabling and systemic impacts). Other terms use are “smart ICTs” and</td>
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</table>
A greenhouse gas is one of several gases that can absorb and emit long-wave (infrared) radiation in a planetary atmosphere. This phenomenon is often termed the greenhouse effect.

Green IT is the study and practice of designing, manufacturing, and using computers, servers, monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal impact on the environment. It includes environmental sustainability, the economics of energy efficiency, and the total cost of ownership, which incorporates the cost of disposal and recycling. Green IT is also about the application of IT to create energy-efficient, environmentally sustainable business processes and practices. IT can support, assist, and leverage other environmental initiatives and help in creating green awareness.

Green IS refers to using IS to enhance and support sustainability across the economy and society and focusing on sustainability initiatives.

A grid network is a kind of computer network consisting of a number of (computer) systems connected in a grid topology.

Hermeneutics refers to the study of the interpretation of written texts, especially texts in the areas of literature, religion and law.

An alternative name to “system” for the concept of whole

Monitors the load condition of motors and adjusts voltage input accordingly.

Interpretivism refers to approaches emphasizing the meaningful nature of people's participation in social and cultural life.

Network-centric advocacy is the adaptation of advocacy and traditional grassroots organizing to the age of connectivity.

The term phenomenology in science is used to describe a body of knowledge that relates empirical observations of phenomena to each other, in a way that is consistent with fundamental theory, but is not directly derived from theory.

Positivism refers to a set of epistemological perspectives and philosophies of science which hold that the scientific method is the best approach to uncovering the processes by which both physical and human events occur.
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<tr>
<td>Precision agriculture</td>
<td>An integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment.</td>
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<td>R&amp;D (Research and Development)</td>
<td>The phrase research and development (also R and D or, more often, R&amp;D), refers to creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.</td>
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<tr>
<td>Radio frequency Identification (RFID)</td>
<td>A technology that uses communication through the use of radio waves to transfer data between a reader and an electronic tag attached to an object for the purpose of identification and tracking.</td>
</tr>
<tr>
<td>Realism</td>
<td>Realism, Realist or Realistic are terms that describe any manifestation of philosophical realism, the belief that reality exists independently of observers, whether in philosophy itself or in the applied arts and sciences.</td>
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<td>Root definition</td>
<td>A Root Definition is a structured description of a system (which is relevant to the problem). It is a clear statement of activities which take place (or might take place) in the organization being studied.</td>
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<td>SBC</td>
<td>Server-based computing (SBC) is a technology whereby applications are deployed, managed, supported and executed on the server and not on the client.</td>
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<td>Smart building</td>
<td>Smart buildings are closely linked to smart grids. They rely on a set of technologies that enhance energy efficiency and user comfort as well as the monitoring and safety of buildings. Technologies include new building materials as well as ICTs.</td>
</tr>
<tr>
<td>SMART framework</td>
<td>A guide for developing ICT solutions. Through standards, monitoring and accounting (SMA) tools, and rethinking (R) and optimising how we live and work, ICT could be one crucial piece of the overall transformation (T) to a low carbon economy.</td>
</tr>
<tr>
<td>Smart grid</td>
<td>A “smart grid” is a set of software and hardware tools that enable generators to route power more efficiently, reducing the need for excess capacity and allowing two-way, real time information exchange with their customers for real time demand side management (DSM).</td>
</tr>
<tr>
<td>Smart ICTs</td>
<td>An alternative term for “Green ICT” and “sustainable IT”.</td>
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<tr>
<td>Smart logistics</td>
<td>A variety of ICT applications that enable reductions in fuel and...</td>
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energy use by enabling better journey and load planning.

**Smart meters**
ICT technologies that reduce energy consumption at the level of the motor, the factory or across a business.

**Smart motors**
ICT technologies that reduce energy consumption at the level of the motor, the factory or across a business.

**Soft Systems Methodology (SSM)**
SSM is an analytical technique that is based on the concept of systems thinking and tries to understand a given problem domain in different circumstances and across multiple perspectives. It does not define rigid steps to follow but is strategic in its approach by employing a top-down procedure, for example, taking a holistic view of the problem rather than looking immediately at the detailed level.

**SSMc**
In any Soft Systems Methodology based intervention, SSMc devotes to the perceived **content** of the problematical situation.

**SSMp**
In any Soft Systems Methodology based intervention, SSMp devotes to the intellectual **process** of the intervention itself.

**T&D**
Transmission and distribution

**Talik**
An unfrozen section of ground found above, below, or within a layer of discontinuous permafrost.

**Telecommuting**
Telecommuting or tele-work is a work arrangement in which employees enjoy flexibility in working location and hours. In other words, the daily commute to a central place of work is replaced by telecommunication links.

**Thin client**
A desktop computer with functionality limited to input/output. The operating system and applications run on central servers and are centrally administered.

**Variable speed drive (VSD)**
Controls the frequency of electrical power supplied to a motor.

**Videoconferencing**
The audio and video transmission of meeting activities

**Virtualisation**
Software allows computation users to reduce hardware assets, or use them more efficiently, by running multiple virtual machines side by side on the same hardware, emulating different components of their IT systems.

**Web 2.0**
Web 2.0 is associated with web applications that facilitate participatory information sharing, interoperability, user-centered
design, and collaboration on the World Wide Web.

**WEEE**


**ZigBee**

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs).
1 CHAPTER 1: INTRODUCTION

As the awareness of the negative effects of Greenhouse Gas Emissions (GHG) continues to increase, central governments’ new stringent environmental legislation, e-waste disposal concerns, and concerns about corporate reputations are pushing businesses and individuals to ‘go green’ (Murugesan & Laplante, 2011). With the support of Information Technology (IT), life and work has been dramatically altered and the productivity, economy, and social well-being have been improved (Murugesan & Laplante, 2011). Now IT has a new role to play, which is helping to build a greener, more sustainable environment whilst gaining benefits for the economy (Murugesan & Laplante, 2011).

In the Green IT special volume of IEEE IT Professional journal, Murugesan (2011) defines Green IT as follows:

“Green IT is the study and practice of designing, manufacturing, and using computers, servers, monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal impact on the environment. It includes environmental sustainability, the economics of energy efficiency, and the total cost of ownership, which incorporates the cost of disposal and recycling. Green IT is also about the application of IT to create energy-efficient, environmentally sustainable business processes and practices. IT can support, assist, and leverage other environmental initiatives and help in creating green awareness.” (p. 1).

The Green House Gas (GHG) emission that IT has contributed as measured by several research projects is responsible for 2 - 3% of overall GHG emissions (Murugesan & Laplante, 2011; Organization for Economic Co-operation and Development, 2010a, p. 204). In fact, the majority of emissions come from other non-IT sectors (Murugesan & Laplante, 2011). Thus a comprehensive application of Green IT across other areas of the economy could gain significant energy savings and help to improve the overall environmental sustainability (Murugesan & Laplante, 2011).

Since Green IT is both an environmental and economic imperative, it will be a top priority for several years to come (Murugesan & Laplante, 2011). There are a number of case studies that show that the reduction of the carbon footprint for business can also reduce costs and increase reputation among the public (Murugesan & Laplante, 2011). Thus the call to deliver sustainable IT solutions is strong and becomes an important task for IT professionals, CIOs, and IT support to accomplish (Murugesan & Laplante, 2011). However, although IT has been widely applied to almost all areas of our activity, whilst offering significant convenience and benefits and transforming society and businesses, it also has brought negative impact on the natural environment, causing various environmental problems (Murugesan, 2010). To this, unfortunately, many IT professionals do not realize these negative impacts on the natural environment (Murugesan, 2010). Nevertheless,
Green IT and Green IT applications will soon be necessities rather than options, thus IT professionals should have a good understanding of Green IT and its potential (Murugesan & Laplante, 2011).

Green ICT is a term that takes the scope of Green IT a step further, which integrates the positive Green IT approaches with the solutions from the telecommunication field, such as video-conferencing, thus Green IT becomes Green ICT (T-systems, 2010). This is the level that this thesis targets – not only covering an area of IT, but also the telecommunication field. It is defined by OECD as follow:

“Green ICTs” is an umbrella term for ICTs with better environmental performance than previous generations (direct impacts) and ICTs that can be used to improve environmental performance throughout the economy and society (enabling and systemic impacts). Other terms use are “smart ICTs” and “sustainable IT”.

For the issues involved with both ICT and the environment, Hasan and Kazlauskas (2009b) pointed out that such problems are so-called “wicked problems”, which is “... ill-defined, with shifting definitions and multiple elements whose conflicting objectives necessitate resolution through a complex, holistic perspective.” (p. 1). Thus, the design of this research has considered the characteristics of the research objective as Hasan and Kazlauskas mentioned, which has been addressed by adopting a holistic systems approach. A methodology is used that is called Soft Systems Methodology (SSM). SSM is defined by Checkland (Checkland & Poulter, 2010) as follows:

“Soft systems methodology (SSM) is an approach for tackling problematical, messy situations of all kinds. It is an action-oriented process of inquiry into problematic situations in which users learn their way from finding out about the situation, to taking action to improve it.” (p. 191)

Moreover, although this research follows a principle of SSM, it does not exactly follow the procedure of SSM due to the specific circumstances of this research. The procedure adopted for this research is a modification of SSM that applies a more holistic perspective – higher than a concept of an “organization” or “corporation”, which commonly SSM addresses – within an interconnected group of stakeholders who have a common concern on a same issue, instead of within a physical organization.

The research topic is considered as an ill-defined problem, thus SSM is adopted not only for answering the research questions but also for exploring the problems of this topic. In another words, the two initial research questions proposed before actually starting this research, are actually “anchors” for the research. This was used as a starting point and to give rise to and to discover more questions and issues about the research topic.

The ICT leasing company was chosen to be the objective of this research. This works as an anchor for Green ICT issues and enabled the researcher to identify and explore Green ICT
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strategic issues on a larger scope – the complexity of Green ICT strategic implementation with interactions with other stakeholders (New Zealand government, green organization, ICT scholar, and IT manager). At the end of this research, a list of recommendations for implementing Green ICT strategies development for ICT companies in New Zealand is proposed.

The thesis is organized as follow: in chapter 2, a holistic study for Green ICT issues is conducted. This includes most of the areas that ICT could impact on in terms of a “Green” concept. Three models are built while reviewing relevant literature, which are Level 1 (figure 4, page 13), 2 (figure 7, page 19) and 3 models (figure 8, page 24). The level 1 model is constructed on a base level, and then more information is added to this base level and forms the level 2 model. Finally, Level 3 model is constructed and proposed based on a more comprehensive review of the literature based on level 1 and 2 models and provides a holistic view on the Green ICT issues. Furthermore, the implications of the three models are also discussed in this chapter.

Chapter 3 provides the rationale for the methodology adopted for this research – Soft Systems Methodology, the research questions, the design of the research, sampling technique, data collection, as well as the data analysis methods. In Chapter 3, possible ethical issues that may happen during this research and ways to avoid them are discussed, in addition the validity of the modelling method in SSM, as well as the limitations of this research are also discussed.

In chapter 4, the result of the survey is presented and discussed. In order to construct conceptual models for the analysis in the process of Soft Systems Methodology (SSM), a questionnaire (see appendix A) was designed to collect data for “CATWOE” with some basic demographics questions. A survey was conducted online using SurveyMonkey and e-mail. Five stakeholder groups (ICT leasing company in New Zealand, ICT scholar, the customer to whom they lease, government body, and New Zealand green group) have been identified and surveyed.

In chapter 5, data collected is analysed following the process of SSM. The “Three Analyses” of SSM (analysis of the intervention, “social systems” analysis, and “political system” analysis) are covered. Moreover, stages 3, 4, 5 and 6 of SSM are addressed (see figure 27 and section 5.5 – 5.7), which are “root definition of relevant purposeful activity systems (stage 3)”, “conceptual models of the systems (holons) named in the root definitions (stage 4)”, and “comparison of models and real world (stage 5)”. Five conceptual models are built based on the data collected from the five participants, and then these are mapped with the level 3 holistic model respectively, which has been constructed from reviewing relevant literature. At the end of this chapter, a summary table is designed for the mapping results.

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1 A CATWOE analysis is a systems thinking tool of SSM to prepare comprehensive root definition models. It is the acronym for Clients, Actors, Weltanschauung, Owners, and Environment.
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The research is concluded in chapter 6. The final stage (stage 6) of SSM is addressed (see figure 27, page 77). In this stage, a list of recommendations that contribute to the development of systemically desirable and culturally feasible solutions is proposed. Furthermore, a model for the development of specific solution is constructed for the relevant stakeholders for this research.

In this chapter, an introduction for Green ICT and its related issues have been briefly discussed, as well as for the methodology that adopted to this research. Moreover, chapter summaries are also provided for each chapter of this thesis. In next chapter, a comprehensive literature review is conducted in order to have an in-depth exploration for Green ICT and its related issues. Whilst, three models are developed.
2 CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION
A literature review is conducted in this chapter. Three models are constructed on different levels based on the result of the literature review. The level 1 model provides a general illustration on Green ICT issues, the level 2 model is an upgraded version of level 1 model with more details, in the level 3 model, a comprehensive exploration is conducted and a holistic model is built with rich details regarding the impact of ICT in terms of a “Green” concept.

The development of the holistic model through the literature review is the first stage of the methodology – Soft Systems Methodology (SSM) (See Chapter 3) that has been adopted for this research. The level 3 model is used in the mapping and in comparing between the real world and the conceptual world in the data analysis chapter.

2.2 LEVEL 1 MODEL

2.2.1 OECD’s framework for Green ICT
The Organization for Economic Co-operation and Development (OECD) has developed their framework for Green ICTs in the “OECD Information Technology Outlook 2010” report as shown below:

Figure 1: Model for Green ICTs

(Organization for Economic Co-operation and Development, 2010a, p. 193)
This framework indicates the three layers of environmental impacts of ICTs (Organization for Economic Co-operation and Development, 2010a, p. 193). They are “Direct impacts (Technology)”, “Enabling impacts (Application)“ and “Systemic impacts (Change in behavior)” (Organization for Economic Co-operation and Development, 2010a, p. 193). The “Direct impacts” refers to the direct impacts of ICT on the environment such as energy consumption, product end-of-life disposal and materials throughput (Organization for Economic Co-operation and Development, 2010a, p. 193). While the “Enabling impact” in the next layer in figure 1 are “second-order effects” (Organization for Economic Co-operation and Development, 2010a, p. 194), which means the impacts arise from the application of ICT that help to reduce environmental impacts across economic and social activities (Organization for Economic Co-operation and Development, 2010a, p. 194). “Systemic impacts” of ICT refers to “…those involving behavioral change and other non-technological factors. Systemic impacts include the intended and unintended consequences of wide application of green ICTs.” (Organization for Economic Co-operation and Development, 2010a, p. 194).

2.2.2 The Level One Model
This model (figure 2) is an upgrade to OECD’s “Framework for Green ICTs” (Organization for Economic Co-operation and Development, 2010a). In this model, the concept “Green ICT” is further refined and extended as the concept of achieving “overall sustainability” in the context of Green ICT. Moreover, this model shows that the positive impacts of ICT are not only covering the environmental aspect, but also support the economy and society in achieving sustainability. On the top level, social, economic and environmental sustainability merge together and ultimately form the overall sustainability. Hypotheses have been formulated and a base level conceptual model has been constructed to interpret the relationship between each element. Five elements are included in this model. They are “ICT”, “Economy”, “Society”, “Environment” and “Purpose of sustainability”. Moreover, arrows in this model show the factors where one element could possibly impact on another. As shown in the model (Figure 2), ICT have impacts on achieving the purpose of sustainability through the implication between it and the economy, society and the environment.
Figure 2: Holistic Model for Green ICT, Level 1

2.2.2.1 Purpose of sustainability
Sustainable development is firstly defined by the Brundtland Commission (1987)’s report in the following terms:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs and it contains within it two key concepts: the concept of ‘needs’, in particular the essential needs of the world’s poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs” (p. 8)

As has been mentioned in the citation above, there are three fundamental elements: technology, social organization and the environment all of which have been defined for the level 1 model (Figure 2). In the years following the Brundtland Commission’s report, the concepts of sustainable development have been further refined and elaborated in the report of IISD (International Institute for Sustainable Development, 2010), which critical roles of technology and social organization are explored. In the report it is suggested that achieving a long-term balance between human
development and the natural environment is essential for the development of sustainability (International Institute for Sustainable Development, 2010).

**Figure 3: The Triple Bottom Line of Sustainability**

As shown in figure 3, a triple bottom line (TBL) has been developed which includes three elements in organizational sustainability, they are: The environment, economic performance, and society (Dao et al., 2011). Dao et al (2011) mentioned:

"By considering people and planet in addition to profit, effects on the environment and stakeholders will be incorporated when contemplating alternatives, leading (presumably) to a more sustainable outcome. In fact, it is argued that long-term profitability is best served by balancing it with social and environmental goals." (p. 4).

Moreover, sustainable development can only be achieved in the long term through appropriate strategies and policies that balance economic growth with social development and with environmental sustainability (International Institute for Sustainable Development, 2010). After viewing literature as discussed above, the researcher finds these concepts of sustainable development, economy, society and environment are the three fundamental elements. Along with the purpose of sustainability and ICT, these elements provide the first level of the proposed model (Figure 2).

**2.3 Implication of Level 1 Model**

Over the last 10-20 years, it has been recognised by many sustainable development policy-makers that it is impossible to achieve the goals of social and economic development, and environmental sustainability without significant technological
innovation (International Institute for Sustainable Development, 2010). If ICT plays a central role in ensuring economic sustainability, it can and must play an equally central role in promoting environmental and social sustainability, both as an industry and as a key element of enabling infra-structure (Dutta & Mia, 2010).

In the last section, elements of this model have been found as shown in Figure 2, the arrows start from “ICT” and finally arrived at the “purpose of sustainability” at the top of the model through “economy”, “society” and “the environment”. All the arrows have been numbered and each of them shows hypotheses of the impacts on one another. There are links that can be defined from the model. Starting from “ICT” and reaching “the purpose of sustainability” at the end, these are: arrow 1-6, arrow 1-4-8, arrow 2-7, arrow 2-5-8, arrow 3-8. Arrow 1-6 and 1-4-8 are involved in economic factors, while arrow 2-5-8 and arrow 2-7 involved in social factors. Furthermore, arrow 3-8 refers to the direct impact of ICT and ICT applications on the environment. The model is also divided into three layers: Layer 1 (Green ICT and its applications), Layer 2 (Green ICT enabled effects/Information Systems) and layer 3 (systemic effect/external factors).

2.3.1 Arrow 1-6
This link shows the impacts of ICT on sustainability through its impacts on the economy. Sustainable development of the economy is an essential element for the overall sustainability of the human world. In fact, Green ICTs have unique potentials for triggering green growth of the economy (Watson, Boudreau, Chen, & Huber, 2009) in the aftermath of 2008-2009 economic crisis. According to the research conducted by OECD (Mickoleit, Reimsbach-Kounatze, Serra-Vallejo, Vickery, & Wunsch-Vincent, 2009), in the economic crisis, ICT is one of the sectors that is facing the negative impacts from the recession (Mickoleit et al., 2009). One of the consequences is the labour layoffs in ICT sector, which is occurring in both ICT goods and services. Some companies have reported there has been over 10% reduction of their workforce within a short period of time (Mickoleit et al., 2009). However, from mid-2008, around one-half of US venture capital flowed into the US ICT sector and ICT-intensive Green technologies, and was directed at research and development (Mickoleit et al., 2009). A survey provide by the research suggests that new media, software and particularly clean ICTs will keep attracting a major share of venture investments (Mickoleit et al., 2009).

In order to restore prosperity from the recession, economic stimulus packets have been adopted by many countries (International Institute for Sustainable Development, 2010). This may help counteract downward pressures on the ICT sector and continently support the diffusion of ICTs in a short period of time (Mickoleit et al., 2009). In the long-term, many governments plan to adopt stimulus package through long-term investments and many of these stimulus plans are
related to the ICT sector or ICT applications (Mickoleit et al., 2009), for instance, the “SMART” technologies such as smart grids, smart transport systems and smart urban systems (The Climate Group & Global e-Sustainability Initiative, 2008).

From another aspect, ICT plays a significant role in improving energy efficiency for buildings and factories that demand power, in power transmission and distribution, and in the transportation sector (The Climate Group & Global e-Sustainability Initiative, 2008). In economic terms, this ICT-enabled energy saving and efficiency improvement could be translated into approximately €600 billion (USD 946.5 billion) of cost savings by the years of 2020 (The Climate Group & Global e-Sustainability Initiative, 2008).

Taking another perspective, employment in ICT sector declined in 2009, especially in semiconductor firms, which have seen a rapid decline in revenue and have experienced a 4% loss in employment while in contract (Organization for Economic Co-operation and Development, 2009d, p. 5). Generally, there was 2-3% drop in large ICT firms (analysis of 80 global ICT firms, survey conducted by OECD) (Organization for Economic Co-operation and Development, 2009d). However, some areas in ICT industry are promoting Green ICTs development and are promising to develop new employment despite this recession (Organization for Economic Co-operation and Development, 2009d). This includes virtualization and cloud computing in which there is increasing ICT employment during this phase of recession (Organization for Economic Co-operation and Development, 2010a). Moreover, there is a rapid growth of around 3-4% in the employment of ICT-specialists in the total business employment in the ICT sector (Organization for Economic Co-operation and Development, 2009d).

2.3.2 Arrow 1-4-8
This link shows the impact of ICT on the environment through the impacts on the economy, which establishes a relationship with the purpose of achieving overall sustainability. For instance, the rising investment in green solutions in both public and private sectors through the tools that ICT offers, such as chips, computers, software and high speed networks (Gurria, 2009). These will help to build a low carbon economy and to tap the economic crisis further to lower energy use and reduce greenhouse gases emission across the entire spectrum of industry (Gurria, 2009).

According to SMART 2020 (2008), adopting ICT-enabled smart solutions in industry (motor systems), logistics, building design and electricity grids could enable significant reductions of emissions across the economy, which could help deliver approximately 7.8 GtCO$_2$e (Billion metric tonnes Carbon Dioxide equivalent) of emissions savings in 2020 (p. 9):
• Industry automation and optimised motor system that supported by ICT could increase industrial efficiency by 10% and would reduce 0.97 GtCO$_2$e in 2020 worth $107 billion (p. 9).

• There are several ways ICT could help improve the efficiency of logistics operation, such as using software to improve transport network design and enabling ICT-based management systems (p. 37). Adopting smart logistics solutions would achieve emission reduction of 1.52 GtCO$_2$e in 2020 and equivalent to $441.7 billion of energy saving (p. 9).

• In 2002, the emissions generated by buildings were 8% of the overall emissions globally (3.36 GtCO$_2$e) and attention is rising in the area of energy which wasted by buildings (p. 41). However ICT-based optimisation, monitoring and feedback tools can be applied to reduce the emissions across every stage of a building’s life cycle (p. 41). Smart building technologies would contribute to emission savings by 1.68 GtCO$_2$e, equal to $340.8 billion (p. 9).

• Smart grids technologies have been identified as the largest opportunities in reduced emissions among those four smart technologies, which could reduce 2.03 GtCO$_2$e by the year of 2020 and this equals to a saving of $124.6 billion energy (p. 9). The name “smart grid” refers to: “A ‘smart grid’ is a set of software and hardware tools that enable generators to route power more efficiently, reducing the need for excess capacity and allowing two-way, real time information exchange with their customers for real time demand side management (DSM). It improves efficiency, energy monitoring and data capture across the power generation and T&D network.” (p. 45).

Another aspect is “Dematerialisation” (Houghton, 2009). According to Hinterberger & Schmidt-Bleek (1999), it refers to “... the concept of industrial metabolism, dematerialization aims at reducing quantitatively the material throughput of the economic system...” (p. 14), while in ICT field, it means “replacing high carbon physical products and activities (such as books and meetings) with virtual low carbon equivalents (e-commerce/e-government and advanced videoconferencing) (The Climate Group & Global e-Sustainability Initiative, 2008, p. 10)”. Newspapers, books and music can be delivered as online digital contents, thus decreasing the use of materials and GHG consumption of traffic (T-systems, 2010). In this category, tele-working is the one which has largest impact on emission reduction among dematerialization ICTs (The Climate Group & Global e-Sustainability Initiative, 2008) — people could work from home rather than commute to their offices (The Climate Group & Global e-Sustainability Initiative, 2008), which could enable up to 260 MtCO$_2$e (Million metric tonnes Carbon Dioxide equivalent) savings each year (The Climate Group & Global e-Sustainability Initiative, 2008). Another important emission saving solution is tele- or video-conferencing systems. Such solutions are:
use of Webcam to enable simple PC-based video-conferencing; room-based, medium-sized solutions that allow users to participant and communicate through large screens; use of special equipment to enable tele-presence, which participants could be displayed on life-size screens that provide an experience of the user is actually be in the room (T-systems, 2010). Similar to tele-working, tele- or video-conferencing can effectively reduce emission by replacing many business trips (5-20% of global business trips (The Climate Group & Global e-Sustainability Initiative, 2008)), and it is supported by tele-working. When people are working at home, they could hold video-conference and this will save time and office space (T-systems, 2010).

However using ICT to increase efficiency and applying this to economic activities can also contribute to unsustainable economic growth and increase the GHG emissions. Tomlinson, Silberman and White (2011) point out that IT professionals must ensure that the energy efficiency increased by applying Green IT aligns with sustainability when making efforts to reduce energy usage (Tomlinson et al., 2011). In an indirect aspect, the reduction in cost of the energy this could probably cause consumers to buy more goods and it could also dramatically increase the number of consumers and share holders, therefore being more harmful to the environment than was prevented by the original energy savings (Tomlinson et al., 2011). In most of the literature reviewed, such effects are called the “rebound effects” of energy efficiency. This refers to the behavioural responses such as people will have greater use of the services (such as the Internet (International Institute for Sustainable Development, 2010), heat and mobile), which energy help to provide (United Kingdom Energy Research Centre, 2007).

2.3.3 Arrow 3-8
This link refers to the impact of ICT on the environment and on achieving overall sustainability. This includes ICT’s direct impacts on the environment (energy consumption, end-of-life disposal and materials throughput (Organization for Economic Co-operation and Development, 2010b) and the application of ICT to address issues of global environmental impact (natural disaster monitoring, tracking man-induced hazards (Institute of Electrical and Electronics Engineers, 2010b), pollution monitoring (Institute of Electrical and Electronics Engineers, 2010a), and environment managing (Houghton, 2009).

E-waste is a major problem for ICT equipments end-of-life treatment. If an overall view of ICT equipment’s product lifecycle – from production and use to disposal is taken, presents environmental challenges (Murugesan, 2010). Various electronic and non-electronic component are being used to manufacture ICT equipment and this process consumes raw materials, water, electricity, chemicals and generates pollution (hazardous waste) (Murugesan, 2010). Furthermore, there are about 800 million metric tons of CO₂ that is generated each year, which accounts for about 2%
of all global greenhouse gases emissions – as much as the emission of the entire aviation industry (Shah, Christian, Patel, Bash, & Sharma, 2010). Moreover the amount of CO\textsubscript{2} the ICT sector consumes is still growing rapidly (Tomlinson et al., 2011).

The enabled impact of arrow 3-8 is heavily supported by sensor technologies. Sensor technologies are not only extensively applied in smart technologies (smart buildings, smart grids, and smart transport and logistics, see arrow 1-4-8) (Weber, 2009), but also have significant support for precision agriculture (e.g. micro-climates monitoring) and animal tracking (Weber, 2009, p. 37), climate change monitoring (Alippi, Camplani, Galperti, & Roveri, 2011), and natural disaster forecasting and warning systems (Georgiou, Clark, Zodiatis, Hayes, & Glekas, 2010).

The aim for applying sensors and sensor networks in precision agriculture is to “maximum production efficiency with minimum environmental impact” (Taylor & Whelan, 2005). In agriculture, problems such as land erosion, soil compaction, salinity and water quality decline have happened because of one off the major concerns of intensive agriculture – over-exploitation (Wark et al., 2007). Sensor technologies play a critical role in solving these problems through measuring and monitoring the health of water and soil quality at various stages (Weber, 2009). There are four areas that sensors and sensor networks are used: “i) plant/ crop monitoring, ii) soil monitoring, iii) climate monitoring and iv) insect-disease-weed monitoring (Weber, 2009, p. 37)”. It also helps farmers tracking herd behaviour, thus managing grazing areas more efficiently to prevent and avoid overgrazing of pastures and land erosion (Weber, 2009). In all, in this field, sensors and sensor networks help people to manage natural resources better (Weber, 2009). However, considering the cost of precision agriculture, to date, most farmers are taking the economic benefits when deciding whether to use sensors and sensor networks for precision agriculture (United States Department of Agriculture, 2007).

There are several areas for sensor networks’ application in environmental monitoring areas. These include: air pollution, water pollution, global warming analysis and facilitated recycling (Atkinson & Castro, 2008). For air pollution monitoring, sensor networks are used for detecting pollution peaks in specific time and locations within cities (Weber, 2009, p. 47). Sensor networks are also deployed in waters to monitor the state of marine lives and the level of pollution (Weber, 2009, p. 47). In the area of global warming monitoring, sensor networks are usually a part of what constitutes the sophisticated IT monitoring systems. For instance, deploying sensors in the ocean to collect data about the environment (e.g. temperature, chemical) and to visualise the situation in order to gain insight from the environmental data (Kehrer et al., 2008). Finally, “waste collection and recycling” is another area that sensor networks can support. With optical sensors, different kinds
of paper and plastic can be identified and allowing them to be put in different bins (Weber, 2009, p. 47).

Sensors and sensor networks are also applied in natural disaster warning systems. For example the “TWERC” (Tsunami Warning and Early Response system of Cyprus), which expands the existing “CYCOFOS” (Cyprus Coastal Ocean Forecasting and Observing System) observatory operating on the south coast of Cyprus with a tsunami detection sensor network (Georgiou et al., 2010). This makes the alert being delivered quicker and useful information about what to do is obtained earlier to citizens (Georgiou et al., 2010).

2.3.4 Arrow 2-7
This link refers to the social impact of ICT on the overall sustainable development. Beyond supporting the growth of future economy, the ICT industry also plays a significant role in achieving social sustainability by “… improving the way societies and governments provide education, healthcare, and services to citizens (Dutta & Mia, 2010, p. 82).” Moreover, the ICT industry provides people with options that allow them to interact with each other, which will create positive changes in a variety of areas in the long-term (Dutta & Mia, 2010). Beyond economic benefits, the ICT industry is uniquely positioned to help build a more socially sustainable future (Dutta & Mia, 2010, p. 61).

It was unthinkable 20 years ago, that ICTs would have dramatically improved the way people study. The Internet provides a wide range of information that is free to access (Dutta & Mia, 2010, p. 83). Tools and social ICTs such as websites, email, digital libraries and virtual classrooms (Atkinson & Castro, 2008, p. 22) are facilitating the sharing of information and knowledge on a large scale (Dutta & Mia, 2010). ICT also has impacts on the healthcare area. In the future, improvements in healthcare will not only come from better medicine and better doctors, but also from managing the information better, thus information technologies will play a critical role (Atkinson & Castro, 2008, p. 32). For instance, it is more efficient for doctors to access patients’ medical data electronically, allowing easily and immediately access to medical test results from laboratories, helping to directly deliver prescriptions to pharmacists, or to a patient who has heart problems where monitoring and alerting doctors when a heart attack comes (Dutta & Mia, 2010). In the field of government services, “e-government” helps to deliver government services to citizens much easier and faster (Dutta & Mia, 2010, p. 65). For example, in many countries, over 70% of people use online services and pay tax in an electronic way (Dutta & Mia, 2010, p. 65). Other services involving transactions such as renewing drivers’ licenses and managing government benefits, are all activities that can be conducted online through the use of ICT (Dutta & Mia, 2010, p. 65). Furthermore, the use of ICT contributes to the improvement of information access and communication for the
public (Dutta & Mia, 2010, p. 66). With the support of social ICTs, the way people access information (e.g. Wikipedia and Google) is changing and users can interact with each other (e.g. virtual reality, blogs, and Facebook) (Dutta & Mia, 2010). One example is the use of social networking websites to conduct job recruitment online (Dutta & Mia, 2010, p. 66). A recent survey conducted in May 2009 shows that 72% of the companies in US plan to increase of use of social ICTs in conducting recruitments (Dutta & Mia, 2010, p. 66). Furthermore, social ICTs such as Web 2.0 technologies, which include the social context can play a positive role in the global challenges of global warming and climate change (Hasan & Kazlauskas, 2009a). The social impact of IT on sustainability supports a network-centric advocacy and offers better transparent of information, knowledge and communication about politics and climate change (Hasan, Ghose, & Spedding, 2009). This democratized knowledge is likely to change the political landscape, in which voters can collaborate (Hasan et al., 2009). This is probably supporting the environmental movement with knowledge sharing and network-centric advocacy (Ghose, Hasan, & Spedding, 2008).

2.3.5 Arrow 2-5-8
This link refers to the impact of ICT on society in terms of the environment and achieving the purpose of sustainable development. For instance, using computer-based simulation models to provide an analysis of sustainable manufacturing and environmental management solutions for enterprises and organizations (Ghose et al., 2008). Web services decreased the need for papers and travelling (Hasan & Kazlauskas, 2009b). Social and economic activities become paperless and are more efficiently enabled by ICT (Hasan & Kazlauskas, 2009a). ICT can be used to establish face-to-face communication environment between users and eliminate the carbon footprint of unnecessary travelling, commuting and producing of all manner of paper documentation (Hasan & Kazlauskas, 2009a). Moreover, with the development of mobile technologies and the ubiquity of the Internet, citizens could monitor and upload the information of the environment by connecting low-weight environmental sensors to mobile phones though Bluetooth (Gouveia & Fonseca, 2008), thus enable the citizen’s participation in the initiatives of tackling climate change.
2.3.6 Layer 1 of the model (arrow 1, 2, 3)

Figure 4: Model Layer 1

This layer (figure 4) shows the *direct impact* of ICT on the environment and the impacts of ICT application on the environment, economy and society. As showed in figure 4, this layer includes arrow 1, 2 and 3. For arrow 1, it refers to the impact of Green ICT that is related to the economy, for instance smart technologies and supporting economic growth. Similarly, for arrow 2, it stands for the impacts of ICT on society such as social ICTs and improving quality of people’s lives. For arrow 3, the impact of ICT on the environment is not only in an aspect of ICT’s physical existence (e.g. emission, disposal and pollution), but also is the same as arrow 2 and 3, which refers to the impact of ICT applications, such as sensors and sensor networks. This layer shows the “first-order” impacts of Green ICTs without any effects between the elements that are being impacted (economy, the environment and society). In addition, the purpose of using ICT as a tool to support the sustainability of these three elements has not been incorporated.

This is the layer that Green ICT targets. These areas include (Dedrick, 2010; Gurria, 2009; International Institute for Sustainable Development, 2010; International Telecommunication Union, 2008b; Murugesan, 2008; Watson et al., 2009):

- Designing energy efficient ICT equipments (computing and telecommunication equipments)
- Design for environmental sustainability
- Power management
- Reducing power consumption of data centres and the its design, layout and location
- Server virtualization
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- Reducing electronic waste from responsibly disposal and recycling ICT obsolete equipments
- Using renewable and clean energy resources
- Methodology, green metrics and assessment tools
- Risk mitigation for environment-related issues
- Eco-labelling of ICT products
- Replacing PC with energy efficient thin clients and the use of cloud computing.

2.3.7 Layer 2 of the model

Figure 5: Model Layer 2 (Layer 1 Embedded)

This layer (figure 5, arrow 4, 5 and Layer 1 embedded) shows the enabling effects of ICT and refers to the term “ICT applications” (Reimsbach-Kounatze, 2009), plus the social and economy impacts on supporting the well-being of the environment which has been enabled by ICT. This means that using ICT as an enabler reduces environmental impacts across society and the economy outside of the ICT sector (Reimsbach-Kounatze, 2009). In this layer, arrow 4 refers to the impacts on the environment from the economy enabled by Green ICT such as reduction of GHG emission from industry and efficient use of natural resources. While for arrow 5, this refers to the social impacts enabled by ICT on the environment, for instance the increase of social awareness and responsibilities on the issues of global warming that have enabled by social ICTs. This layer adds the “second order” effects from ICT in this model, which presents a broader view with four elements (the environment, economy, society and ICT) interacting with each other as a system.

This layer is the level that Green IS is targeting. This layer includes the following aspects (International Institute for Sustainable Development, 2010; Lacobelli, Olson, & Merhout, 2010; Lefevre, 2009; Organization for Economic Co-operation and Development, 2009e; Watson et al., 2009):
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- Green IT
- Dematerialization
- Sensing systems
- Renewable and clean energy systems
- Tracking environmental information
- IT systems and sustainability
- Optimizing Logistics and transportation to avoid and minimise energy consumption
- Technological innovation and sustainability
- E-government, e-commerce, e-education, digital media
- Systems thinking in sustainable development
- Supports meetings and teamwork when employees are distributed throughout the world
- Promoting remote computer administration and telecommuting to reduce the emission of transportation.

2.3.8 Differences between Green ICT (Layer 1) and Green IS (Layer 2)
A report provided by T-Systems (2010) indicates that Green IT can be purchased or ordered directly, and that intelligent solutions are available that contribute to sustainability (p. 3). Moreover the convergence of IT and telecommunication technologies are increasing, thus it is possible to take the Green IT concept a step further to Green ICT (T-systems, 2010). In this report, the relationship between Green IT and Green ICT is described as:

“The positive approaches of Green IT need to be combined with solutions from the field of telecommunications, such as video-conferencing: Green IT is turning into Green ICT” (T-systems, 2010, p. 3).

Furthermore, Hasan and Kazlauskas (2009a) pointed out that traditionally, people tend to meet each other face-to-face and routinely “go to work”. However as the awareness of “Green” concept grows, it can be seen that such activities that increase significant carbon footprints, such as travelling and the use of paper (Hasan et al., 2009) are not within the ‘Green’ concept. For these issues, potential IT solutions have been available for some time, for instance tele-commuting, group decision support systems, tele-conference, the virtual office and the digital office (Hasan & Kazlauskas, 2009a). However, despite the fact that the benefits have been shown (Hasan, 2005; Hasan & Crawford, 2007), there has not been widespread uptake of ‘Green’ ICT practices, which have been meet by resistance because of a combination of cultural, social, economic and technical changes to the way things are done (Hasan & Kazlauskas, 2009a). With the concerns of environmental aspects and adding “C” (Communication) into “ICT”, the collaborating and conferencing tools that enabled by ICT are now firmly back on the agenda (Hasan et al., 2009).
Even though the terms “Green IT” and “Green IS” are commonly grouped together by many authors, there are differences between the two concepts (Lacobelli et al., 2010). Murugesan (2008) gives this definition for green IT:

“Green IT refers to environmentally sound IT. It is 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 communication systems – efficiently and effectively with minimal or no impact on the environment. Green IT also strives to achieve economic viability and improved system performance and use, while abiding by our social and ethical responsibilities.” (p. 25)

In the context of Green IT, sustainability refers to “global environment sustainability”, which means “a characteristic of Earth’s future in which certain essential processes persist for a period of time comparable with human lives” (Tomlinson et al., 2011, p. 87). Green IS refers to using IS to enhance and support sustainability across the economy (Watson et al., 2009) and society (Hasan et al., 2009) and focusing on sustainability initiatives (Lacobelli et al., 2010). This therefore is a broader view than Green IT that only focuses on technical artefacts.

In other words, Green IT is working on utilizing IT machinery to make a more energy efficient model in the most effective way possible in order to create a more efficient system, and users may then implement Green IT initiatives (Lacobelli et al., 2010). Green IS is targeting the creation of more sustainable footprints for users and society (Lacobelli et al., 2010).
2.3.9 Systemic effects (6, 7 and 8, and Layer 1 and 2 embedded)

Figure 6: Model Layer 3 (Layer 1 and 2 Embedded)

The external factors outside layer 2 and 1 refer to the systemic effects of ICT. The direct and enabling effects of ICT on sustainable development have been discussed in the previous section. There is a general agreement on the systemic effects of ICT (International Institute for Sustainable Development, 2010). In the longer term, ICTs can play a critical role in achieving the goal of sustainability by enabling the transformation of economic, social and governance structures, and facilitating fundamental changes in cultural behaviours in terms of values, attitudes and behaviour of individuals, as citizens and consumers (International Institute for Sustainable Development, 2010; Organization for Economic Co-operation and Development, 2010c).

This layer includes arrow 6, 7 and 8 and these show the impact of economy, society and the environment on achieving the overall sustainability under the support of Green ICT (direct impact and enabled impact). Specifically, for instant, arrow 6 may refer to the sustainable growth of economy under a concept of green digital economy, the use of renewable energy resources and sustainable way of taking natural resources for manufacture. Arrow 7 could refer to the empowerment of people enabled by social ICT, which will contribute to the sustainability of communities. It also refers to the better interaction between people by improved information sharing and enhance understanding with the support of social ICTs. For the environmental aspect, arrow 8, with the support from economy, society (supported by Green ICT), and Green ICT, the biggest issue considered at present is
GHG emissions, which could be reduced and the negative consequences could be lessened. This arrow also refers to tackling pollution and ecosystem preservation.

2.4 **LEVEL 2 MODEL**

This level of framework is constructed and upgraded based on the Level 1 model (see last section, figure 2 or 6). New elements and impacts which were discovered from the analysis process in last section are used as the information which enriching this level 2 model (figure 7). There are upgrades addressed in following areas:

1. The ICT layer is expanded into two more sub-areas: technologies infrastructure and technologies management;
2. Organization is included as one of the elements;
3. The relationship between economy and society in terms of ICT and sustainability is established;
4. Mutual impacts have indicated and are included in this model as the bi-directional arrows showed in the figure (figure 7); and
5. Impacts are categorised and grouped together to gain a better understanding of the issue.

This model contains seven elements and has been divided into three levels, which are technical infrastructure and technical management in the technology (Green ICT) layer, organization, society and economy with the technology (ICT) layer in the industry (IS/Green ICT application) layer, and the systemic effects, environment and purpose of sustainability. Other nodes in the industry/IS cluster include organizational impacts, social impacts and economic impacts. There are links to the external cluster via environmental impacts and the purpose of sustainability. The hypotheses formed are represented as the causal links between the nodes in the framework.
Chapter 2: Literature Review

Figure 7: Level 2 Model

Purpose of sustainability

TF: Technical Factor
IF: Industry Factor
SF: Social Factor
EF: Environment Factor

External factors/
Systemic effects
2.4.1 Technology cluster (Green ICT)
Within the technical infrastructure node, any ICT innovation that moves the OECD towards a greener ICT-based economy are supported. These could include:

1. Cloud computing, Virtualization, 3R (Recycle, reuse and reduce) of disposal e-waste, energy efficiency, reduce carbon credits, and dematerialization;
2. Develop new (green) ICTs; and
3. ICTs in supporting public communication (Web 2.0, e-learning).

The technology-focused hypotheses are:

**TF1:** Technical infrastructure has an effect on the ways in which green IT is managed
Efficient green IT management methods could reduce energy consumption, thus decreasing green house gas emissions. This will also have an effect on SF1 (there are green organizational impacts on technical management).

**TF2:** There are green organizational impacts on selection and use of technical infrastructure
Green ICT infrastructure such as cloud computing, thin-client and virtualization will have organizational impacts. New energy-efficient hardware will also have green organizational impacts.

**TF3:** The technical management of green IT has societal impacts
Social ICTs such as Web 2.0 technologies, e-learning and e-government could give strong support to enable public communication, which, in turn may contribute to the diffusion of green ICT concepts, as well as a way to apply dematerialization (Dematerialization refers to “… the concept of industrial metabolism, dematerialization aims at reducing quantitatively the material throughput of the economic system.” (Bartelmus, Bringezu, & Moll, 2000).

2.4.2 Social impacts
In the societal cluster for a green ICT-based economy the following factors are considered:

1. The long-term balance between human development and the natural environment;
2. Any change of customers’ interests and government’s green policies; and
3. How to meet green policies, public opinion and changes of customers’ interests.

The societal hypotheses therefore are:

**SF1:** There are green organizational impacts on technical management
New management methods could help organizations to manage ICT infrastructure efficiently so that energy consumption could be reduced thus decreasing GHGs emissions.

**SF2:** There are societal impacts that influence Green ICT in organizations
Chapter 2: Literature Review

In 2009, World Trade Organization and United Nations Environment Programme published the *Trade and Climate Change* report to illustrate large-scale research projects completed to identify impacts of climate change on the economy as well as the possible solutions and opportunities to these issues (World Trade Organization & United Nations Environment Programme, 2009). There are also societal and governmental responsibilities in protecting the environment.

**SF3:** The purpose of sustainability will have an economic impact

In 1992, the Brundtland Commission Report defined sustainable development as “*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (International Institute for Sustainable Development, 2010, p. 4). In order to achieve sustainability, in terms of the economy, International Institute for Sustainable Development (2010) state in their 2010 Commentary, “*The Digital Economy and the Green Economy: Opportunities for Strategic Synergies*” as follows: “*This can only be done in the long run through policies and strategies that balance economic growth with social development with environmental sustainability.*” (p. 4)

### 2.4.3 Industry impacts

Industry-based considerations for Green ICT-based economy include:

1. Creating jobs by new green economy with customers’ requirements changing;
2. New business opportunities in Green ICT products; and
3. Raising and driving the direction of the economy to sustainability.

The industry-focused hypotheses are:

**IF1a:** Green IT organizational impacts will affect the economy

For instance, the decrease of the energy consumption will increase organizations’ competitiveness by dramatically reducing the electricity costs.

**IF1b:** The economy will have an impact on Green IT organizations

Green ICT has been promoted as a means to future economic growth (Organization for Economic Co-operation and Development, 2009; World Trade Organization & United Nations Environment Programme, 2009) through governmental green ICT strategies, customer’s new interests on green products and the practice of organizations’ social responsibility on the environment.

**IF2a:** Economic aspects of green ICT will have an impact on the economy

**IF2b:** Social impacts will be felt by the influence of Green ICT on the economy
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There may be a causal relationship between increases in customers’ interests in green products and the economy. There may also be a link between both social and economic impacts as organizations adapt and choose to apply Green ICT.

2.4.4 External factors
The environmental cluster for a Green ICT-based economy include:

1. Considerations for reducing energy and raw material taking from the ecosystem;
2. Reducing over consumption of natural resources, green house gases emission, and pollution (e-waste);
3. Tackling climate change, pollution and eco-system decline; and
4. Saving costs, increasing efficiency, and decreasing negative impacts of the economy on the environment.

EF1a: The environmental impacts of Green IT will have an impact on the economy

EF1b: The economy will have on the environmental impacts of Green IT.

There may be a reciprocal causal relationship between preserving and using natural resources efficiently.

EF2: The environmental impacts of Green ICT will impinge on the purpose of sustainability

Hasan et al (2009) pointed out that “Environmental concerns that threaten the very existence of the human race are arguably the most important issues of our time. (p. 4)” As the response to this serious issue to the human race, issues, such as pollution, global warming and climate change (EF2) are addressed in this hypothesis (EF2). Perhaps it should be the task for all people who come from different sectors of the society, working together towards a sustainable future, as well as the IS and ICT sectors.

EF3: Green IT infrastructure will have an impact on the economy

For instance, pollution such as e-waste and green house gas (GHG) emission reduction will have an impact on the economy.

2.5 Level 3 Model
This Level 3 model has been constructed based on Level 1 (figure 2) and 2 models (figure 7). Compared with the level 1 and 2 models, the level 3 (figure 8) model presents a holistic view of the impacts of ICT and sustainable development with a wider range and deeper exploration. The areas that have been included are as follows:

1. One of the elements, “the environment”, in the level 2 model, is extended into six sub-elements in order to gain a better understanding of the relationship between ICT and the environment. This includes “greenhouse
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- gas emissions, global warming, climate change, pollution, ecosystems, and natural disasters.

2. “Social awareness” and “politics” are presented in the level 3 model, instead of the element “society” in the level 2 model.

3. Some single bi-directional arrows are divided into two opposite or multiple arrows.

4. All the arrows are labelled with numbers.

Arrows in this model represent ways in which the elements are connected. Literature is reviewed and used to provide evidence to support these connections. The literature review is conducted in the context of ICT.
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Figure 8: Level 3 Model

- **Ecosystem**
  - Negative impact
  - Taking, and providing resources
  - Negative impact

- **Pollution**
  - Negative impact
  - Aerosol particles block the full effect of GHGs radiative forcing to heat the Earth
  - Green house gases emission
  - New shipping routes and exploitation resources in the Arctic

- **Economy**
  - Negative impact
  - ICT support and accelerate economy
  - Reduce GHG emission through smart ICT applications
  - E-waste, ICT applications
  - Market driven
  - Support

- **Technology (ICT)**
  - Negative impact
  - People with skills and awareness in Green ICT support its development
  - ICT support communication, increase social awareness, education

- **Social Awareness**
  - Affect policies and strategies making
  - Raising of awareness and providing education

- **Politics (policies strategies and legislation)**
  - Tackling environmental problems through implementing Green ICT policies strategies

- **Human Organisations**
  - Social responsibilities guide human’s behaviour

- **Politics (policies strategies and legislation)**
  - Industry participant in the implementation of Green ICT policies and strategies

- **Natural disasters**

- **Climate change**
  - Lead to
  - Antarctic ice melting, extra green houses gas release from the soil.
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2.5.1 ICT and pollution (1)
In this section, two aspects for the impact of ICT on pollution are discussed: one is the toxic waste generated from ICT’s product lifecycle (producing, using and end life disposal), which is causing pollution with heavy metals and other toxic organic substances. On the other hand, the applications of ICT can play a significant role on tackling pollution across other sectors, such as the use of remote sensing technologies and Geographical Information Systems (GIS) on monitoring air, soil and water pollutions.

2.5.1.1 E-waste
According to United Nations University (UNU)’s statistics (Huisman et al., 2007), the total annual global volume of e-waste (WEEE\(^2\)) is likely to reach 40,000,000 metric tons a year by 2010 (United Nations Environment Programme, 2011). With the prosperity of the ICT industry, the problem of e-waste has increased and the industry is grappling with this problem (Infiniti Research Limited, 2009). With the advancement of ICT, consumers and organisations are constantly upgrading ICT equipment, causing an increase in adoption and reduction in the lifetime of ICT products (Infiniti Research Limited, 2009). E-waste has been generated from ICT equipment such as CD-ROMs, hard drives, copiers, printers and cell phones and is the fastest growing sources of waste globally (Ansari, Ashraf, Malik, & Grunfeld, 2010).

The process of manufacturing, using and disposing of ICTs requires energy and materials, which in turn generates waste, including toxic waste in the form of heavy metal and this can lead to pollution (Houghton, 2009). There are three main categories of these waste substances released during the recycling process (Sepúlveda et al., 2010): “(i) original substances, which are constituents of electrical and electronic equipment; (ii) auxiliary substances, used in recycling techniques; and (iii) by-products, formed by the transformation of primary constituents” (p. 29). Failure to dispose of e-waste sustainably can lead to various types of pollution (Sepúlveda et al., 2010). This happens especially in developing countries such as China and India (Kojima, 2010). The poor WEEE recycling techniques these countries use are generating pollution that affects both local ecosystems and the people conducting the recycling processes and residents living near these areas (Sepúlveda et al., 2010). Concern about e-waste have been raised over a number of years (Sepúlveda et al., 2010). WEEE can contain thousands of substances and some of which are toxic, while others have a market value such as gold, silver and copper (Sepúlveda et al., 2010).

The inadequate disposal and recycling of e-waste and recovery of valuable substances practices can be potentially harmful to the environment (Sepúlveda et al., 2010). Heavy metals and brominated and chlorinated flame retardants can affect soil and water and be taken up by biota\(^3\) (Sepúlveda et al., 2010). In addition, dust particles that are laden with

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\(^2\) Waste Electrical and Electronic Equipment

\(^3\) Biota is the total collection of organisms of a geographic region or a time period, from local geographic scales and instantaneous temporal scales all the way up to whole-planet and whole-timecale spatiotemporal scales.
heavy metal and flame retardants can be released into atmosphere due to poor dismantling activities (Sepúlveda et al., 2010). These dust particles would either re-deposit near the emission site or could be transported across a large area (Sepúlveda et al., 2010). Moreover, the dust incorporated in wastewater can go into soil and water systems then infiltrate into underground water and then be taken up by biota (Sepúlveda et al., 2010). In addition, the environmental fate of ashes, particles and fumes containing heavy metal and PBDEs emissions are similar when burning e-waste (Sepúlveda et al., 2010). However, inappropriate burning and metallurgical treatment of e-waste can release extremely hazardous chemical by-products including furans and polyhalogenated dioxins (Sepúlveda et al., 2010). These by-products are very toxic and among the most hazardous anthropogenic pollutants (Allopp, Costner, & Johnston, 2001; Sushil & Batra, 2006). Furthermore, Sepúlveda (2010) explains the completed processes about how e-waste burning activities can lead to pollution:

“...and one of their most important formation pathways is the burning of plastic products containing flame retardants and PVC. As copper (Cu) is a catalyst for dioxin formation, Cu electrical wiring coated with chlorine containing PVC plastic contributes to the formation of dioxins. Chlorinated and brominated dioxins and furans (PCDD/Fs and PBDD/Fs), and mixed halogenated compounds like the polybrominated–chlorinated dibenzo-p-dioxins (PBCDDs) and polybrominated–chlorinated dibenzofurans (PBCDFs) can be formed during WEEE burning. Once emitted into the atmosphere, dioxins and furans are dispersed into the environment, and because of their semi-volatile and hydrophobic properties, they tend to accumulate in organic rich media. Higher brominated or chlorinated congeners degrade more slowly and tend to partition more into lipids. They often deposit near the sources of emission while the lower halogenated compounds are typically transported over longer distances (Fig. 1). In the atmosphere, dioxin and furans are subject to photodegradation and hydroxylation... (p. 31)”

As described above, serious pollution can be generated from the process of inappropriate dispose and recycle of e-waste (WEEE). These could have severe impacts on the environment, ecosystems and human health.

2.5.1.2 ICT’s applications on tackling pollution
With the fast development of industrialization and urbanization globally, pollution problems have become one of the regular topics in every country around the world (Han & Cui, 2009).

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4 Polybrominated diphenylethers (PBDEs) are members of a broader class of brominated chemicals used as flame retardants; these are called brominated flame retardants, or BFRs. There are dozens of congeners, or varieties of the basic chemical type, of PBDEs.
Currently there are several types of pollutions that are of concern, such as soil pollution, water pollution and air pollution (Han & Cui, 2009). ICTs, in particular sensors and sensor networks, are being used to tackle pollution in the field of environmental monitoring (Weber, 2009, p. 47). Water and air pollution monitoring are the two main areas that ICTs can support (Weber, 2009, p. 47).

Air pollution is caused by vehicle emissions, industrial emissions and volatile organic compounds (W. Chen & Chen, 2010). The contaminants or pollutant substances are released into the air and this can lead to several issues and most of which are health-rated (W. Chen & Chen, 2010). In recent literature, many air pollution monitoring systems in urban and rural areas utilize wireless systems and sensor networks (W. Chen & Chen, 2010). Scientists increasingly rely on the tools enabled by ICT and use these to understand and tackle air pollution (Atkinson & Castro, 2008). For example, the application of Zigbee based wireless sensor network in air pollution monitoring (Han & Cui, 2009), use of mobile GPRS-sensors array for air pollution monitoring (Al-Ali, Zualkernan, & Aloul, 2010) and using sensors from satellite to monitor the air pollution of a city in order to gain a high spatial distribution of it (Lim, MatJafri, Abdullah, Mohd, & Wong, 2007).

With the rapid development of civilization, water pollution nowadays has become a serious issue and a source of human disease (Tian & Wang, 2010). ICTs have become an indispensable tool in understanding and monitoring water pollution (Atkinson & Castro, 2008). For instance, scientists deployed radiometric calibration of TM\textsuperscript{5} remote sensors under Huangpu river in Shanghai to help provide a better spatial knowledge of environmental variables and improve the water quality information content and also to limit monitoring costs (Yanling, Hong-en, Xiaohua, Yalei, & Jianfu, 2006). Moreover, sensors and sensor networks have also been applied to reduce water pollution caused by agricultural runoff (Atkinson & Castro, 2008, p. 77). For example, sensors and sensor networks can ensure that fertilizers are applied efficiently and effectively (Atkinson & Castro, 2008, p. 77). In addition, pesticides and herbicides also can be applied efficiently with the support of smart sensor technologies, which in turn reduces the impact of these chemical substances being released into soil and surrounding bodies of water (Atkinson & Castro, 2008, p. 77).

2.5.2 ICT and greenhouse gas emissions (2,5-3)

The amount of carbon dioxide in the atmosphere is increasing and can contribute to climate change (Intergovernmental Panel on Climate Change, 2007b). The ICT sector and ICT products contribute to a significant volume of greenhouse gases (GHGs) emission and this sector is growing rapidly (Tomlinson et al., 2011). Recently, there were three major studies (see table 1, 2 and 3) that have attempted to assess the ICT sector’s global carbon footprint (Organization for Economic Co-operation and Development, 2010a). These results show that: the ICT sector accounts for about 2-3% of global CO\textsubscript{2} emissions (Organization for Economic Co-operation and Development, 2010a). Moreover, due to the rising diffusion of ICTs and

\textsuperscript{5}Thematic Mapper
the Internet across economies, this share is expected to increase (International Energy Agency, 2009c). This has lead to an increasingly large cost to business (T-systems, 2010). Thus, in order to reduce ICT’s own GHG emission and energy consumption, increasing energy efficiency of ICT infrastructure and making intelligent use of hardware becomes a necessary task (T-systems, 2010; Watson et al., 2009). On the other hand, ICT provides us with tools and opportunities to limit and reduce GHG emission through numerous applications, such as dematerialization, smart motor systems, smart logistics, smart buildings and smart grids (The Climate Group & Global e-Sustainability Initiative, 2008). According to Smart 2020 (The Climate Group & Global e-Sustainability Initiative, 2008), ICTs could deliver approximately 7.8 GtCO₂e (Billion metric tonnes Carbon Dioxide equivalent) of emissions savings in the year of 2020 and enable about $946.5 billion of energy cost savings (p. 9).

2.5.2.1 ICT sector and ICT products contribute to GHG emissions
In 2007, three major studies were conducted by The Climate Group and Global e-Sustainability Initiative (The Climate Group & Global e-Sustainability Initiative, 2008), OECD &IEA (International Energy Agency, 2009a, 2009b), and Herzog (Herzog, 2009; Malmodin, Moberg, Lundén, Finnveden, & Lövehagen, 2010) to access the global carbon footprint of the ICT sector and its products (Organization for Economic Co-operation and Development, 2010a, p. 206). Despite their methodologies and research scopes, these results were significantly different to each other, but the results indicated similar findings: the ICT sector shares 2-3% of global CO₂ emissions and this number is expected to rise due to the diffusion of ICTs and the Internet across the global economy (International Energy Agency, 2009c).

Table 1: Global CO₂ and GHG Emissions of ICTs

<table>
<thead>
<tr>
<th>Year Research Conducted</th>
<th>ICT CO₂ emissions (mn tonnes)</th>
<th>ICT GHG emissions (mn tonnes)</th>
<th>ICT share of overall CO₂ emissions (%)</th>
<th>ICT share of overall GHG emissions (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>661</td>
<td>2.3</td>
<td></td>
<td></td>
<td>(The Climate Group &amp; Global e-Sustainability Initiative, 2008)</td>
</tr>
<tr>
<td>2007</td>
<td>830</td>
<td>1.8</td>
<td></td>
<td></td>
<td>(Mingay, 2007)</td>
</tr>
<tr>
<td>2007</td>
<td>1,160</td>
<td>2.5</td>
<td></td>
<td></td>
<td>(Malmodin et al., 2010)</td>
</tr>
</tbody>
</table>

(Organization for Economic Co-operation and Development, 2010a, p. 204)

Table 1 shows the results of three assessments. They are significantly different to each other in terms of methodologies and scopes (Organization for Economic Co-operation and Development, 2010a, p. 204). In addition, an internationally recognized definition of ICT was not used in these studies such as the one provided by OECD (Organization for Economic Co-
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operation and Development, 2009c). Thus adds difficulties to the comparison (Organization for Economic Co-operation and Development, 2010a, p. 204).

In another aspect, the manufacturing phase of ICT accounts for less than 1% of global GHG emissions among other major industry sectors (Organization for Economic Co-operation and Development, 2010a, p. 206). Table 2 provides a comparison between the global GHG emission of ICT manufacturing and other major industry sectors (Organization for Economic Co-operation and Development, 2010a, p. 205):

Table 2: Shares of ICT and Selected Industry Sectors in Global GHG Emissions

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity generation</td>
<td>25</td>
</tr>
<tr>
<td>Vehicle manufacturing</td>
<td>10</td>
</tr>
<tr>
<td>Oil and gas production</td>
<td>6</td>
</tr>
<tr>
<td>Iron and Steel manufacturing</td>
<td>5</td>
</tr>
<tr>
<td>Chemicals manufacturing</td>
<td>5</td>
</tr>
<tr>
<td>Cement manufacturing</td>
<td>4</td>
</tr>
<tr>
<td>Aluminium manufacturing</td>
<td>0.8</td>
</tr>
<tr>
<td>ICT manufacturing</td>
<td>0.6</td>
</tr>
</tbody>
</table>

(Organization for Economic Co-operation and Development, 2010a, p. 205)

In terms of ICT’s carbon footprints in individual countries, Table 3 shows that at least 10% of national electricity is consumed by ICTs during the use phase and this is equivalent to 2-5% of domestic CO₂ and GHG emission (Organization for Economic Co-operation and Development, 2010a, p. 206).

Table 3: National Electricity and Carbon Footprints of ICTs

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>ICT electricity consumption (GWh)</th>
<th>National electricity consumption (%)</th>
<th>ICT share in national electricity consumption (%)</th>
<th>ICT CO₂ emissions (mn tonnes)</th>
<th>National CO₂ emissions (mn tonnes)</th>
<th>ICT share in national CO₂ emissions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2005</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>7.9</td>
<td>525</td>
<td>1.5</td>
</tr>
<tr>
<td>European Union</td>
<td>2005</td>
<td>214,500</td>
<td>2,691,000</td>
<td>8.0</td>
<td>98.3</td>
<td>3,921</td>
<td>2.5</td>
</tr>
<tr>
<td>France</td>
<td>2008</td>
<td>58,500</td>
<td>425,882</td>
<td>13.7</td>
<td>4.9</td>
<td>401</td>
<td>1.2 (7.5)</td>
</tr>
<tr>
<td>Germany</td>
<td>2007</td>
<td>55,400</td>
<td>527,352</td>
<td>10.5</td>
<td>22.6</td>
<td>956</td>
<td>2.4</td>
</tr>
<tr>
<td>Japan</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>Portugal</td>
<td>2007</td>
<td>..</td>
<td>..</td>
<td>1.0</td>
<td>82</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2006</td>
<td>47,769</td>
<td>344,690</td>
<td>13.9</td>
<td>25.9</td>
<td>555</td>
<td>4.7</td>
</tr>
<tr>
<td>United States</td>
<td>2000</td>
<td>97,000</td>
<td>3,499,285</td>
<td>2.8</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>United States</td>
<td>2007</td>
<td>..</td>
<td>..</td>
<td>150.0</td>
<td>6,094</td>
<td>2.5</td>
<td>..</td>
</tr>
</tbody>
</table>

(Organization for Economic Co-operation and Development, 2010a, p. 206)

2.5.2.2 Increase energy efficiency of IT infrastructure and hardware (Green IT)
The area this section discusses refers to the field of “Green IT”. There are definitions that have been made for Green IT in several research papers (listed below by time):
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The Denmark Ministry of Science Technology and Innovation (2008)’s definition for Green IT is:

“Green IT can be defined as research in- and use of IT in an efficient and environmentally friendly manner.” (p. 10)

Murugesan (2008) defines Green IT as follows:

“Green IT refers to environmentally sound IT. It is 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 communication systems- efficiently and effectively with minimal or no impact on the environment. Green IT also strives to achieve economic viability and improved system performance and use, while abiding by our social and ethical responsibilities.” (p. 25)

Lamb’s (2009) definition for Green IT is:

“Green IT has many different aspects. In this book, we use the terms green IT, green computing, and green data centres. Green IT— as used here—is the most comprehensive because it includes all computing, inside and outside the data centre. The data centre.” (p. 2)

While T-Systems (2010) states as follows:

“Green IT” is what analysts, manufacturers and providers call all IT solutions that save energy at business organizations. These include hardware, software and services. Where hardware is concerned, energy-efficient desktop PCs, thin-client architectures and data-centre hardware offer answers, and so do energy supply and cooling systems.” (p. 3)

Ansari et al (2010) define Green IT as follows:

“Green IT addresses environmental impacts of the whole IT life-cycle, ranging from designing an IT device, to its use and its end-of-life management. Highlighting issues such as CO2 emissions, the concept emphasizes the need to adopt practices that will lead to less energy consumption and IT-waste, whether dealing with small devices such as mobile phones or large energy intensive data centres.” (pp. 1-2)

Although these definitions of “Green IT” differ from each other in terms of scope and impacts, they point to a similar direction, which is to increase IT infrastructure’s energy efficiency, contribute to the reduction of IT’s environmental burdens (including e-waste) and reduce the cost in business activities through adopting energy efficient hardware and solutions. With the support of Green IT, 7.8 billion tonnes of CO2 equivalent can be saved in 2012, which is equal to 15% of all GHG emissions (Unhelkar, 2011). There are six major
aspects in Green IT, which include e-waste; data centres and servers; PCs, monitors, and workstations; software; and metrics (Ruth, 2009).

2.5.2.2.1 E-waste
Issues on e-waste have been addressed in a broader perspective in terms of Green ICT in section 2.5.1.1. Although this is one of the areas in “Green IT’, according to this literature review, the researcher finds there is no relationship between increasing energy efficiency and e-waste.

2.5.2.2.2 Data centres and servers
There are more than three million data centres in the world (T-systems, 2010). Their energy and emission costs are a major concern in Green IT analysis (Ruth, 2009). These data centres generate more than half of all the costs of electricity for IT, from small equipment to numerous servers and associated workstations (Ruth, 2009). In 2005, the power consumption for cooling cost for servers worldwide had reached $26 billion and it is expected to rise to add another $40 billion in the following year (Ruth, 2009). There are solutions for solving this problem, in two ways: increasing power efficiency and adaptation of Green IT solutions (Carter & Rajamani, 2010). Both software and hardware play a critical role in the increase of energy efficiency (Carter & Rajamani, 2010). This is shown in figure 9 as follows:

**Figure 9: Energy Efficiency in Data Centres: How to Save Up to 75% of Energy Costs**

![Figure 9: Energy Efficiency in Data Centres](Energie-Agentur, 2009)

Figure 9 shows the possible operations of the reduction of energy consumption for data centres (Energie-Agentur, 2009). It is expected that there will be a 75% reduction of energy costs from data centres by adapting these operations (T-systems, 2010).

Virtualization plays a significant role (Cameron & Tech, 2009) by improving energy efficiency of servers through decommissioning unnecessary physical servers and a higher utilization of the remaining, higher energy-efficient servers (Dawson, 2008). Furthermore, energy efficiency for servers and data centres also can be increased through consolidating a
number of fragmented data centre landscapes into a few data centres (Symantec & The Alchemy Solutions Group, 2009, p. 6), and also through applying outsourcing from IT service providers (Brown Wilson Group & Black Book Outsourcing, 2009).

2.5.2.2.3 PCs and workstations
PC, monitor and workstation as individual IT equipment do not consume large amounts of electricity, however there are billions of them in the world, thus the total electricity consumption is huge (Ruth, 2009). Along with a better design for hardware in terms of power saving, adapting energy efficient thin clients is another important way of improving energy efficiency (Davis, 2008). Davis (2008) defines thin client as follow: “When deployed in scale, a thin-client architecture driven by centralized servers in a traditional SBC\(^6\) model can offer functionality similar to that of desktops with local processing — but with significant power savings (p. 4).” Thin-client terminals are much more efficient in power consumption, which only consume anywhere from 6-50 watts (traditional PC consume 150-350 watts), and most of this is cooling that is taken by server (Davis, 2008). This could contribute to 24% power reduction and promises a related 23% decrease in CO\(_2\) emissions (Davis, 2008).

2.5.2.2.4 Software
Software could be designed as being power efficient. For an operating system, Microsoft Windows 7 is design with a strong focus on reducing the overall power consumption of computer platform (Microsoft, 2009). Virtualization software is a major contributor to servers’ and data centres’ power efficiency, in terms of managing large quantities of servers, their electricity assignment, and cooling systems (Davis, 2008). In addition, another type of software – power management tools are also delivering multimillion dollars in electricity saving (Davis, 2008). These software tools help to manage the power efficiency for complicated power systems, such as residential buildings or an individual PC (Davis, 2008).

2.5.2.2.5 Metrics
Green IT’s compliance is difficult to measure (Ruth, 2009). There are many measurement approaches that exist in the IT area, with the most common ones being Energy Star (Environmental Protection Agency, 2010) and EPEAT (Green Electronic Council, 2010a, 2010b). At a micro level, the Telecommunications Energy Efficient Ratio (TEER) is targeting the energy efficiency of individual ICT equipment (ATIS Exploratory Group on Green, 2010, p. 14), while at a macro perspective, a holistic standard has been approved by UN, called the “Triple Bottom Line” (see figure 3), which contains three aspects of sustainable management: economic, ecological, and social outcomes (Pereau, Doyen, Little, & Thébaud, 2011; Ruth, 2009). This is standard and has an IT component and is associated with the global ecological footprint (Ruth, 2009).

\[^6\] Server Based Computing
2.5.2.3 ICT’s applications on limitation and reduction of GHG emissions (5-3)

Although ICT sector’s own carbon footprint is growing, ICT’s applications on the other hand could enable emission reductions by smart integration of ICT into new ways of living, learning, working, operating and travelling (The Climate Group & Global e-Sustainability Initiative, 2008, p. 10). This is estimated to enable five times greater emission saving than the ICT sector generates (The Climate Group & Global e-Sustainability Initiative, 2008, p. 29). In the field of ICT applications, smart technologies and dematerialization are two major areas that provide opportunities for the potential for ICTs to drive emission reduction (The Climate Group & Global e-Sustainability Initiative, 2008, p. 29).

2.5.2.3.1 Dematerialization

Dematerialization is a concept that refers to: “The substitution of high carbon products and activities with low carbon alternatives. (The Climate Group & Global e-Sustainability Initiative, 2008, p. 29)” , which focuses on replacing “atoms” with “bits” (Seungdo, Hyeon-Kyeong, & Hyoung Jun, 2009). For example replacing physical face-to-face meetings with video-conferencing, replacing paper work with “e-” (e. g. e-government, e-commerce, and e-learning), or storing information in a digital form like CDs and hard drives (The Climate Group & Global e-Sustainability Initiative, 2008). If dematerialization was measured, it would have a contribution of 500 MtCO₂e (Million metric tonnes of CO₂ equivalent) for emission reduction in 2020 (The Climate Group & Global e-Sustainability Initiative, 2008). This is just less than the total emissions of Australia in 2005 (The Climate Group & Global e-Sustainability Initiative, 2008). However, compared with the application of Green ICT (smart buildings, smart logistics, smart motor systems, and smart grids) in other industry sectors, as opportunity in emission reduction, this is relatively small (The Climate Group & Global e-Sustainability Initiative, 2008).

2.5.2.3.2 “Smart” ICTs

According to the Organization for Economic Co-operation and Development (2010a), “Smart” ICTs is another term that refers to “Green ICT”:

“‘Green ICTs’ is an umbrella term for ICTs with better environmental performance than previous generations (direct impacts) and ICTs that can be used to improve environmental performance throughout the economy and society (enabling and systemic impacts). Other terms use are ‘smart ICTs’ and ‘sustainable IT’. ” (p. 192)

Based on the calculation from Smart 2020 (The Climate Group & Global e-Sustainability Initiative, 2008), the efficiency opportunities in industry, power, building and transport enabled by Smart ICT applications would be remarkable. A reduction of 7.3 GtCO₂e (Billion metric tonnes of CO₂ equivalent) in total by the year of 2020 (The Climate Group & Global e-Sustainability Initiative, 2008). In smart 2020 report, there are four major areas for smart ICTs that have been identified (The Climate Group & Global e-Sustainability Initiative, 2008, p. 9): smart motor systems, smart logistics, smart buildings, and smart grids.
Industrial activity contributes a large amount of GHG emission globally, responsible for 23% (9.2 GtCO\textsubscript{2}e) of overall emissions in 2002 (The Climate Group & Global e-Sustainability Initiative, 2008, p. 9). Industry consumes nearly half of all the global electricity, and industrial motor systems – the heart of industrial activities will be responsible for 7% of global carbon emissions (The Climate Group & Global e-Sustainability Initiative, 2008, p. 32). An industrial motor can be “smart”, which can be adjusted to be power efficient, often through an Intelligent Motor Controller (IMC) and Variable Speed Drives (VSD) (The Climate Group & Global e-Sustainability Initiative, 2008, p. 33). Due to the lack of information about power consumption of motor systems in factories and where savings can be made, ICT’s role in the short term is providing data for power consumption to business so that they can save power costs by improving manufacturing systems (The Climate Group & Global e-Sustainability Initiative, 2008, p. 33).

As a result of globalisation of economic growth, the logistics sector is growing rapidly (The Climate Group & Global e-Sustainability Initiative, 2008, p. 32). Thus the GHGs emission of the logistics sector is also increasing rapidly, which is responsible for 14% of global emissions (The Climate Group & Global e-Sustainability Initiative, 2008, pp. 36-37). Generally speaking, logistics activities are not efficient in the areas where large operations exist, for instance packaging, storage, transport, purchase from customer and waste (The Climate Group & Global e-Sustainability Initiative, 2008, p. 36). There are a number of ways that ICT could contribute to a “smart” logistics. According to Smart 2020 this includes:

“...software to improve the design of transport networks, allow the running of centralised distribution networks and run management systems that can facilitate flexible home delivery services. Specific levers include intermodal shift, or moving to the most efficient type of transport, eco-driving, route optimisation and inventory reduction. There are a number of specific technologies that could already enable more efficient logistics...” (The Climate Group & Global e-Sustainability Initiative, 2008, p. 37)

The amount of GHG emissions from the world’s buildings reached 8% of total global emissions in 2002 and the number is predicted to increase to \(-11.7\) GtCO\textsubscript{2}e (billion metric tonnes of carbon dioxide equivalent) in 2020 (The Climate Group & Global e-Sustainability Initiative, 2008, p. 41). However, ICT could offer green solutions in order to mitigate GHG emitted by buildings (The Climate Group & Global e-Sustainability Initiative, 2008, p. 41). According to Smart 2020 (The Climate Group & Global e-Sustainability Initiative, 2008) Smart buildings refer to “a suite of technologies used to make the design, construction and operation of buildings more efficient, applicable to both existing and new-build properties. (p. 41)”. For instance Building Management Systems (BMS), which control heating, ventilation, air-conditioning, lighting, and electric/ electronic appliances (BEDEN, 2007). With individual room control provided by BMS, heating and cooling cost can be saved up to 30%, and even more if used in combination with automatic window blind control (BEDEN, 2007).
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According to a report – *Technology Roadmap: Smart Grids*, the term smart grid refers to:

"A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users." (Organization for Economic Co-operation and Development & International Energy Agency, 2011, p. 6)

A set of software and hardware tools are used to enable generators to route power more efficiently. The electricity sector is estimated to account for 24% of global emissions in 2002 and is expected to have 14.26 GtCO₂e in 2020 (The Climate Group & Global e-Sustainability Initiative, 2008, p. 45).

2.5.3 ICT and social awareness (4)

In this section, the researcher found that, in terms of supporting sustainability development, there are impacts of ICT on social awareness about sustainability issues. The development of social ICTs has dramatically enhanced the communication between people, and information is shared at a faster speed and could diffuse further. ICT has become a powerful tool for knowledge sharing and advocacy for “Green” concepts. In addition, innovations are taking place in the education sector. Increasingly new curricula have been designed in terms of “ICT and sustainability” in institutions and universities around the world.

2.5.3.1 ICT and social awareness of climate change

Climate change has become one of most important issues in our time and it threatens the existence of the human race (Hasan et al., 2009). A survey conducted by James and Hopkinson (2009) identified that: social awareness about “Green” concepts is still lacking amongst ICT staff and departments in organizations. Actions need to be taken to increase their awareness of business benefits that Green ICT can provide (James & Hopkinson, 2009). On the other hand, the social awareness about climate change has been greatly increased by the support of ICT for the public, in particular, the World Wide Web (Hasan et al., 2009). The availability of information and knowledge about climate change issues has been increased by ICT, in terms of science, economics and politics (Hasan et al., 2009). Moreover, with Web 2.0, as a social ICT, Ghose, Hasan and Spedding (2009) pointed out that it can be used for: “…allowing people to communicate, coordinate and collaborate in a way of reduce their carbon footprint (p. 20).” As one of the most pressing “wicked problems” humankind is facing, climate change and its interrelated environmental problems are very complex (Hasan & Kazlauskas, 2009b). With the support of Web 2.0, the balance of power with respect to knowledge is shifting to the Web from the hand of governments, publishing houses and media moguls (Hasan et al., 2009). Nowadays, people to use the Web more frequently for searching for information, such as Google and Wikipedia (Hasan et al., 2009). This makes knowledge and information more democratic and transparent, which, in turn will contribute to the environmental movement with network-centric advocacy and knowledge sharing (Hasan et al., 2009).
2.5.3.2 Green ICT Education

In 27 May 2009, OECD held the High-level OECD conference on ICTs, the Environment and Climate Change in Helsingør, Denmark (Organization for Economic Co-operation and Development, 2009a). As one of the major outcomes from the conference, many participants called for innovations in the education sector, with education and training around the skills set for green jobs needing to be promoted (Organization for Economic Co-operation and Development, 2009a). This is the key to assure the supply of ICT-skilled engineers to develop and deploy Green ICT (Organization for Economic Co-operation and Development, 2009a). Education in Green ICTs is identified as a critical factor for a country’s competitiveness of its ICT industry (Organization for Economic Co-operation and Development, 2009a). Governments should develop and provide funding for education and research and development in Green ICT field, and develop information campaigns to raise awareness around Green ICT and sustainable consumption (Organization for Economic Co-operation and Development, 2009a).

However, even through the call of supporting Green ICT education is strong from governments, in the area of higher education, Green ICT educators are confronted with barriers that significantly reduce the adoption of “Green” principles and practices within the ICT curriculum (Mann, Muller, Davis, Roda, & Young, 2009). Mann et al. (2009) pointed out there are three barriers “Green” ICT educators could facing: (1) limitation of knowledge about ICT and sustainability issues for ICT educators; (2) the feeling that environmental sustainability is not significantly linked with ICT; and (3) poor accessibility of or lack of resources for the integration of sustainability in the ICT curriculum. From a positive aspect, Cai (2010) believes that the integration of sustainability into computing education will help prepare graduates with multi-disciplinary knowledge, computing competencies and computation thinking to build a sustainable future. Merhout (2011) points out that there is a crisis in the enrolment in IT courses in higher education and “Green/ Sustainability ICT” courses could attract students’ interests. He suggests that universities could integrate “Green/ Sustainability” concepts into IT and IS curriculum so that they could generate an enrolment increase (Merhout, 2011). For the design of the “Sustainability/Green” curriculum for ICT, Mann, Smith and Muller (2008) conducted a survey among computing educators who attended the ITiCSE 2008 conference and the result were very positive – the participants had an excellent awareness and strong recognition on the integration of “Green/ Sustainability” concepts into ICT curriculum. The authors recommend that:

“We recommend that the decision be made to integrate sustainability education into every programme, rather than develop a stand-alone course. This demonstrates the commitment to a core value and belief, that the goal of sustainability in the world, will only be achieved through everyone learning to live and work sustainably.” (Mann et al., p. 129)
In addition, Pattinson and Gordon (2011) also mentioned the importance of “Green” design in the Information Systems curriculum: “We believe that sustainability (or green-ness) should be a significant element of the IS curriculum, equal in importance to areas such as professionalism and ethics, but distinct from those.” (p. 4)

2.5.4 ICT and economy (5)

In the context of achieving the goal of sustainability, ICT and the economy are interacting cooperatively with each other: the development of Green ICT is playing a critical role in supporting the sustainability of the economy, helping the world to restore prosperity from the worst economic crises in decades (Dutta & Mia, 2010). On the other hand, new markets for ICT products and services are emerging and growing rapidly in areas such as education, business, economic, healthcare, human development, and government (Murugesan, 2011). Customers including governments, firms and private sectors show a strong demand for Green ICT products and services, and this is predicted to rise sharply in the next two years (PricewaterhouseCoopers, 2008). Furthermore, in order to recover from the economic crisis, many governments have adapted economic stimulus packages (Mickoleit et al., 2009).

2.5.4.1 ICT and the sustainable development of economy

As the global economy starts to recover from one of the most serious economic crisis in decades, ICT is about to play an increasingly significant role as a critical enabler of sustainable and renewed growth (Dutta & Mia, 2010). Both the Organization for Economic Co-operation and Development (2009) and the World Economic Forum (2010) has mentioned in their reports that governments’ investing in ICT sector will help to drive economy towards sustainability, which investing in ICT is a key driver of economic development for developed and emerging markets alike (Dutta & Mia, 2010). The investment to ICT can be direct, for instance in high speed broadband networks and next generation switching technology, or it also can aim at stimulating the use of ICT to secure social and economic benefits, such as “smart” and energy efficient ICTs (Guellec & Wunsch-Vincent, 2009, p. 13). A result from these investments can be to help to increase the level of competitiveness and improve the overall performance of a country’s economy in the long run, as well as increasing employment in the ICT sector (Dutta & Mia, 2010).

2.5.4.2 The impact of economy on ICT

The researcher found that the development of ICT in a “Green / sustainable” direction is strongly driven by the market. A survey conducted by PricewaterhouseCoopers (2008) with 148 executives in the technology, telecom and digital media sectors, shows that green demand for technology comes from all sectors – government, business and consumers, and is in every instance rising.
Figure 10: Overall Green ICT Demand Growth

<table>
<thead>
<tr>
<th></th>
<th>Today</th>
<th>In two years</th>
<th>Percentage increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>48%</td>
<td>75%</td>
<td>(+58%)</td>
</tr>
<tr>
<td>Government</td>
<td>57%</td>
<td>76%</td>
<td>(+33%)</td>
</tr>
<tr>
<td>Consumer</td>
<td>54%</td>
<td>72%</td>
<td>(+33%)</td>
</tr>
</tbody>
</table>

(PricewaterhouseCoopers, 2008, p. 11)

Figure 10 shows that 57% of these respondents think that demand for green technology emanating from government customers is strong (40%) or very strong (17%) (PricewaterhouseCoopers, 2008, p. 11). Respondents expected that this number would increase to 76% (PricewaterhouseCoopers, 2008, p. 15). For business customers, 48% of the participants said the demand for Green technology was very strong (6%) or strong (42%) (PricewaterhouseCoopers, 2008, p. 11). Furthermore, in private sectors, consumers’ demand was also predicted to increase, 54% of the executives seeing that green demand was very strong (15%) among consumers or strong (38%) (PricewaterhouseCoopers, 2008, p. 11).

Another aspect is the impact of economic stimulus packages on ICT sector. This will affect the ICT sector directly and indirectly (Mickoleit et al., 2009, p. 6). The short term aim of these packages is to stimulate demand and restore the health of the banking system, protect jobs and inject cash into the economy (Mickoleit et al., 2009, p. 6). These could bring positive impacts to the ICT sector in terms of helping to counteract downward pressures from the economic crisis, and sustain the diffusion of ICTs (Mickoleit et al., 2009, p. 6). In the long term, many governments plan to foster growth through long term investments in the ICT sector (Mickoleit et al., 2009, p. 6). Most of these investments related to the ICT sector or the application of ICT, such as smart grids, smart transports systems and smart urban systems (Mickoleit et al., 2009, p. 6). The question is: “how current ICT policies should be maintained or rethought in the context of the economic crisis and what is the appropriate balance between continuity in proven ICT policies and change in the form of ad hoc crisis measures.” (Mickoleit et al., 2009, p. 6).
2.5.5 ICT and organization (6, 7)
The researcher found that the impacts between ICT and organizations seem to be mutual to each other. In the context of Green ICT, organizations are heavily benefit through the use and applications of Green ICT, while oppositely, Green ICTs are being developed by the ICT sector based on organizations’ requirements.

2.5.5.1 Organizations are benefit from adopting Green ICT (6)
There are several aspects that an organization can benefit from in adopting Green ICT or smart ICT solutions. Directly, ICT solutions can support business process by streamlining processes and potentially helping companies to reduce CO₂ emission by improving the utilization of resources and allowing them to be shared (T-systems, 2010). Moreover, T-systems (2010) mentioned in the report “White Paper Green ICT Greening of Business” as follow:

“ICT also permits in-depth monitoring of energy consumption and CO₂ emissions throughout the value chain, so processes and organizational structures can be enhanced accordingly. The potential savings are particularly great in industries with extensive, complex supply chains. Examples involving automotive components, and the development and manufacture of cars, are presented here to illustrate this.” (p. 13)

Indirectly, organizations can also benefit from customers’ demanding and rewarding for companies that act in an environmentally sustainable way, thus increase a company’s competitive advantage. Moreover Green ICT can support organizations through of use Green ICT to increase business efficiency so that cost can be reduced (Hedman & Henningsson, 2011).

2.5.5.2 The trend of development of Green ICT (7)
The direction of development of Green ICT is accelerated by organizations. Harmon and Demirkan (2011) suggest that “IT managers need to move beyond first-wave green IT strategies of energy savings and regulatory compliance to address second-wave corporate sustainability requirements. A new framework offers IT managers a roadmap for the journey.” (p. 19). He points out that the first-wave is often referred to as the term “Green IT”, and its primary emphasis is to help organizations to reduce computing-centric energy consumption in data centres and throughout the organization (Harmon & Demirkan, 2011). Coming next, the second wave of “sustainable IT” is emerging (Harmon & Demirkan, 2011). This will increase the focus on the external world and would be services-oriented, promoting IT not only to exploit customer and organizational opportunities but also to target broader areas such as social problems (Harmon & Demirkan, 2011).

Furthermore, Unhelkar (2011) identified the trend for Green IT in the next five years. He divided this five year period into three periods of time, which are immediate trends, medium-term goals and the long-term outlook (see figure 11 below) (Unhelkar, 2011).
The current trends of Green IT addressed by IT management (Unhelkar, 2011) focus on efficiency and effective use of IT resources to reduce the impacts on the environment. On one hand, individual users can also help by bringing simple changes into their daily activities, which may include recycling paper and toner, turning off monitors and using printers more efficiently (Unhelkar, 2011). For medium goals, Green IT will try to: “...capitalize on the promise of IT to reduce carbon emissions across all organizational processes and methods. Lose alignment of green IT with business processes, goals, and standards opens up opportunities for businesses in the economics of energy efficiency.” (Unhelkar, 2011, p. 57).

For a long-term outlook, Green IT will support decision-making for customer, employees and partners with respect to environmental issues and capitalise on people’s new attitude on the natural environment (Unhelkar, 2011). Governments, organizations, industries and academic fields will work closely and create a collaborative green space (Unhelkar, 2011).

### 2.5.6 Organization and economy (8)

The potential of Green ICT’s market (arrow 5 in figure 8), the benefits an organization will receive from the adaptation of Green ICT (arrow 8 in figure 8), and the future development trends of Green ICT, have been discussed in the last three sections (arrow 5, 6, 7 in figure 8). In this section, the opportunities provided and enabled by Green ICT for organizations to restore and grow from the recession of the economic crisis are discussed.

Currently there are two issues of concern in the area of global economic and social development. These are: the challenge of environmental sustainability and the rich potential of ICT (Nadia, 2011). Nadia (2011) points out the opportunities created from the integration of digital economy and green economy for the recovery from the recent
economic crisis. There are opportunities in two dimensions for organizations in the ICT sector: short-term opportunities and long-term opportunities (Mickoleit et al., 2009). These factors show the factors that may benefit the ICT sector from the demand of other related industries. Furthermore, ICT plays a significant role in the reconfigurations of value chains, times of restructuring and emerging regulations, leading to the demand for certain types of ICT services to increase, for instance software (Mickoleit et al., 2009). These are listed below (Mickoleit et al., 2009, p. 29):

**Short-term opportunities**

- The investment from public sector and emerging economies on ICT sector is continually increased
- Supported by economic recovery packages
- Cost cutting measures of ICT could lead to more energy efficient ICTs
- Downturn leads to greater efficiencies and restructuring of ICT sector
- Due to the great reliance of ICT and the Internet, ICT budgets are hard to be compressed
- In order to cut cost and to restructure, the use of ICTs will be increase, such as productive tools, CRM, and information management.

**Long-term opportunities are:**

- Supported by economic recovery packages in the long-term
- ICT sector continues to be a leading source of employment, innovations, and value-added
- Leading the growth in digital content applications
- Green IT and low-carbon economy drives growth: smart grids, sensors, sensors networks, and tele-working
- Innovation priorities and new ICT Research and Development drives growth: ICT, bio- and nano-technologies)
- Climate change, energy efficiency, aging and health as the socio-economic challenges and these will drive the growth
- Back-office operations, and globalisation and consolidation of value chains lead to increased use of information management, for instance, to improve transparency of public sector and financial markets.

**2.5.7 ICT and natural disasters (9)**

ICTs have been widely applied across climate-related disaster management. Natural disasters are an example of ICT use, in which data needs to be acquired and analysed under severe time pressure (Yap, 2011, p. 10). There are different phases in a disaster management cycle where ICTs can be applied. According to Yap (2011, p. 9), these phases are: preparedness, response, recovery/rehabilitation and reconstruction. Figure 12 shows the disaster management cycle:
In figure 12, there are four phases in this continuum. The reconstruction phase is often referred to by researchers as having three sub-phases: disaster mitigation, disaster risk reduction and disaster prevention phases (Yap, 2011, p. 9). The preparedness phase includes actions taken in advance of natural disasters such as establishing training front-line responders and early warning systems (Yap, 2011, p. 9). The disaster response phase refers to the immediate actions that need to be taken after disasters, in order to protect and save lives, properties and infrastructures (Yap, 2011, p. 9). After the physical impacts of the hazard event, search and rescue operations need to be conducted (Yap, 2011, p. 10). Essential physical and social systems will be re-established, such as providing people replacement homes and local economy reestablishment (Yap, 2011, p. 10). Generally, this is referred to as the disaster recovery phase (Yap, 2011, p. 10).
As showed in figure 13, many ICTs have been applied to the management of natural disasters, according to Yap (2011), these applications include:

1. Early warning effective delivery (p. 13): Television, radio (satellite radio), telephones (mobile and fixed, cell broadcasting, satellite remote sensing technology (Zhiheng et al., 2010);
2. Stable, reliable communication in severe environments (p. 17): Mobile phones, wireless Ad-hoc mesh networks with GPS, e-mail and the Internet, radio;
3. Graphic picture creation for disaster monitoring (p. 19): Geographic Information System (GIS) (T. Chen, Li, & Yuan, 2010; Jinyu, Guangfa, Mingfeng, Zhilei, & Junming, 2010), satellite remote sensing technology (Aziz & Aziz, 2011), GPS; and
4. Accountability and transparency improvement (p. 20): Web 2.0 tools.

2.5.8 ICT applications on tackling environmental issues (10, 11, 12)
ICTs are critical in helping people to understand the environment and enhance the ability to deal with the environmental changes (International Telecommunication Union, 2008a, p. ix). Advanced high speed processors along with the rapid diffusion of the fast broadband networks and the development of web-based services are changing the way that climate
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research, studying and decision-making are conducted (International Telecommunication Union, 2008a, p. ix). Environmental process modelling is becoming more accurate, predictive and comprehensive through the support of high speed processors, which uses large accurate and detailed data sets that are increasingly linked together through grid networks (International Telecommunication Union, 2008a, p. ix). A new generation of Web services such as virtual global browsers and new ICTs such as Geographic Information System (GIS) and Web services are replacing stand-alone software platforms (International Telecommunication Union, 2008a, p. ix). Furthermore, the Internet is playing a critical role in supporting environmental research, learning and decision-making (International Telecommunication Union, 2008a, p. ix).

For the applications of ICTs on tackling environmental issues and relevant management practices, International Telecommunication Union (2008a) has categorised this into six clusters (see figure 14):

**Figure 14: ICT Application Categories**

ICT Application Categories

2.5.8.1 **ICT Applications on Environmental Observation Category**

Having a comprehensive observation, understanding, assessment and prediction of the environmental problems, particularly global climate change is essential for mankind (Imaoka
et al., 2010). One category of ICTs’ applications is to address this area. It includes: climate, atmosphere, water (Alippi et al., 2011; Imaoka et al., 2010), ice (Fabra et al., 2010; Ferre-Lillo et al., 2009; Youcun, Bo, Baisheng, & Tianding, 2010), ocean, land (Heinsch et al., 2006), and soil (Wang, Lv, & Cao, 2011) monitoring and data recording technologies (International Telecommunication Union, 2008a, p. 41). Monitoring Systems such as data collection and storage tools, climate and meteorological related recording and geo-referenced data formats, as well as GIS (International Telecommunication Union, 2008a, p. 41).

2.5.8.2 ICT’s Applications on Environmental Analysis Category
The next stage of environmental data collection is to analysis the data. It needs to be compared and analysed through using various processing and computational tools such as climate, atmosphere, water, ocean, land, and soil quality assessments tools (Guoyu, Wei, & Bi, 2011; International Telecommunication Union, 2008a; Wang et al., 2011; Zhang, Lei, & Zhang, 2011). For instance, technologies used to analysis GHG emissions and air pollution (W. Chen & Chen, 2010; Han & Cui, 2009) in atmosphere, and water tracking and quality (International Telecommunication Union, 2008a; Li, Liu, Peng, & Liu, 2009; Youcun et al., 2010).

2.5.9 E-waste pollution to human health (13)
The concern on electric and electronic waste (e-waste) is growing rapidly. Due to the rising demand for consumer electronics, hazardous chemicals may be released from the materials that are used in the manufacture of computers and similar devices, if the disposal is inappropriate (World Health Organization, United Nations Environment Programme, & Republique Gabonaise, 2008). E-waste contains many toxic heavy metals, such as Lead, mercury, tin, and cadmium, and also organic compounds, such as phthalates and flame retardants (BFRs) (Swedish Environmental Protection Agency, 2011). These toxic substances could result in a range of human health problems. Tables have been developed in two categories: metals and inorganic compounds and organic compounds (Swedish Environmental Protection Agency, 2011):

2.5.9.1 Metals and inorganic compounds

<table>
<thead>
<tr>
<th>Toxic compound</th>
<th>Parts where it is found</th>
<th>Health problems it could cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (Sb)</td>
<td>Plastic, batteries, electrical solder, and CRT glass</td>
<td>Dermatitis, irritation of respiratory tract, and interfering with normal function of the immune system</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>Microwave frequency integrated circuits (MMICs), infrared light emitting diodes (LEDs), laser diodes and solar cells</td>
<td>Tumour formation in the lungs, urinary bladder, kidneys and on the skin</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Coffee pots, toasters, irons, and heaters</td>
<td>The asbestos fibres may be inhaled into the lungs and cause lung cancer</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>Fluorescent lamps, sparkplugs, and “getter plates” in vacuum</td>
<td>Water soluble forms of barium is harmful if get uptake</td>
</tr>
<tr>
<td>Toxic Compound</td>
<td>Parts where it is found</td>
<td>Health problems it could cause</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>Relays springs and solders, and computer motherboards</td>
<td>Develop Chronic Beryllium Disease (CBD) if long term exposure to beryllium and causing emphysema and fibrosis of the longs. Also causing skin disease</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>Cathode ray tubes (CRTs), batteries, PVC formulations.</td>
<td>Highly toxic, causing kidneys and bone structure damage, development of hypertension and heart disease, and the inhalation of cadmium oxide fumes or dusts can cause lung cancer.</td>
</tr>
<tr>
<td>Chromium (Cr[VI])</td>
<td>Steel alloys</td>
<td>Long time exposure can cause permanent eye injury, damage kidney and liver, dusts can cause lung cancer</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>PC-boards, relays, switches, cables, wires, lead free solders and electromagnetic motors.</td>
<td>Causing anaemia if get uptake, high concentration may cause gastrointestinal distress, respiratory tract irritation, kidney, liver damage, and immunotoxicity.</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Solders on PC-boards, monitors, lea-acid batteries</td>
<td>Damage brain, reproduction, kidney, nervous and blood systems.</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>Batteries, switches and relays</td>
<td>Damage blood system, liver, brain and kidney</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>Batteries and electron guns of CRTs.</td>
<td>Causing stomach aches and adverse effects in kidney and blood if ingested in high doses Long-term exposure can cause lung cancer</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>Solar cells, Photocopying machines</td>
<td>Cause selenosis, which the major sign are nail brittleness, hair loss and neurological.</td>
</tr>
<tr>
<td>Tin (Sn) and organo- tin</td>
<td>Metallic-tin can be found in Solders and Lead-tin alloys. Organo-tin mainly can be found in PVC plastics.</td>
<td>Metallic-tin is relatively non-toxic. However the orgno-tin much more toxic than metallic-tin It damages brain and effects memory and cause impaired learning</td>
</tr>
<tr>
<td>Yttrium (Y)</td>
<td>CRTs and LEDs</td>
<td>Few studies have been conducted in this area. Exposure to some of Yttrium compounds may cause lung disease.</td>
</tr>
<tr>
<td>Zinc</td>
<td>CRTs</td>
<td>Excess zinc uptake can be harmful. In can damage stomach lining.</td>
</tr>
</tbody>
</table>

(Swedish Environmental Protection Agency, 2011, pp. 36-42)

### 2.5.9.2 Organic compounds

<table>
<thead>
<tr>
<th>Toxic Compound</th>
<th>Parts where it is found</th>
<th>Health problems it could cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brominated flame retardants (BDRs)</td>
<td>Plastics, foams and PC-boards</td>
<td>Long-term exposure to BFRs can adverse effects brain and skeletal development, reduce reproductively for women</td>
</tr>
<tr>
<td>Dioxins: Brominated (PBDD/F), chlorinated (PCDD/F) and mixed (PBCDD/F)</td>
<td>Form when burning plastics</td>
<td>Long-term exposure can cause carcinogenicity, lymphoid disorders, reproductive disturbance and teratogenicity</td>
</tr>
<tr>
<td>Br-compounds</td>
<td>Form when burning plastics</td>
<td>Poorly research, however some evidences show that they are harmful for humans and the environment</td>
</tr>
<tr>
<td>Polychlorinated</td>
<td>Transformers and capacitors</td>
<td>Damage liver, causing immunosuppression,</td>
</tr>
</tbody>
</table>
### Chapter 2: Literature Review

<table>
<thead>
<tr>
<th>Substance</th>
<th>Source</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biphenyls (PCBs)</td>
<td>Insulated wires and capacitors</td>
<td>Neurotoxicity, tumour promotion, endocrine disruption, and reproductive toxicity</td>
</tr>
<tr>
<td>Polychlorinated naphthalenes (PCNs)</td>
<td>Toxins include effects on reproduction and nervous and systems, liver, digestive tract and skin.</td>
<td></td>
</tr>
<tr>
<td>Chlorinated paraffins (CPs)</td>
<td>CPs are very lipophilic and persistent in human bodies. Long-term exposure to SCCPs (Short Chains CPs) may cause tumours and cancers. However, few of studies have addressed this area.</td>
<td></td>
</tr>
<tr>
<td>Chlorinated benzenes</td>
<td>Negative effects on liver, foetus development, They also promoting tumour, disrupt endocrine.</td>
<td></td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons (PAHs)</td>
<td>Effect reproduction system, endocrine disruption, developmental toxicity and immunotoxicity. May cause tumour</td>
<td></td>
</tr>
<tr>
<td>Nonylphenol ethoxylate (NPE) and nonylphenol (NP)</td>
<td>Effect on sperm function and DNA damage in human lymphocytes</td>
<td></td>
</tr>
<tr>
<td>Organophosphorus flame retardants</td>
<td>Inhibit a key enzyme in human blood and in androgen hormone reception.</td>
<td></td>
</tr>
<tr>
<td>Phthalates</td>
<td>PVC cables and wires</td>
<td>Negative effects on reproduction system</td>
</tr>
<tr>
<td>Fluorinated compounds from Teflon</td>
<td>Most of them are very toxic to human and animals (e.g. HF, MFA and COF2).</td>
<td></td>
</tr>
<tr>
<td>Liquid crystals</td>
<td>LCDs</td>
<td>Irritant, corrosive and sensitize to the skin.</td>
</tr>
<tr>
<td>Nanoparticles</td>
<td>quantum dots in lasers and silver nanoparticles, and carbon nanotubes in semiconductor chips</td>
<td></td>
</tr>
<tr>
<td>Toner dust</td>
<td>Photocopiers and laser printers</td>
<td>Cause respiratory tract irritation</td>
</tr>
</tbody>
</table>

(Swedish Environmental Protection Agency, 2011, pp. 43-56)

#### 2.5.10 Pollution and global warming (14)

The effects of aerosols are one of the most difficult factors to include accurately in estimates of radiative-forcing at local, regional and global scales – some of the particles could absorb solar radiation and some could reflect it (United Nations Environment Programme, 2009a, p. 10). These aerosol particles come from a myriad of anthropogenic sources produced when people use diesel engines, burn fuel, or clear forests (United Nations Environment Programme, 2009a, p. 10). The particles that reflect radiation are more common than those that absorb it and they create a mask that blocks the full effect of greenhouse gas radiative-forcing to heat the Earth (United Nations Environment Programme, 2009a, p. 10). This aerosol particles cause air pollution and health problems for human on the earth surface and from atmospheric brown clouds at height (United Nations Environment Programme, 2009a, p. 10).
2.5.11 The impact of greenhouse gas emission on global warming (15)

Figure 15: The Greenhouse Effect

As shown in figure 15, the Earth has a temperature control system, and greenhouse gases are part of this system (United Nations Environment Programme & GRID-Arendal, 2002). There is about one third of the solar radiation hitting the earth and being reflected back to space, the other two thirds is absorbed by atmosphere and most of this absorption is by oceans and land (United Nations Environment Programme & GRID-Arendal, 2002). As a result, the earth’s surface becomes warm and emits infrared radiation. The greenhouse gases include carbon dioxide, water vapour, methane, nitrous oxide and ozone, trap the infrared radiation (United Nations Environment Programme & GRID-Arendal, 2002).

Naturally, GHGs are generated from animals’ exhalation, from which animals produce carbon dioxide, and plants absorb carbon dioxide during photosynthesis and store it within their material structures (United Nations Environment Programme, 2009a). Bacteria and other organisms also decompose plant material and release carbon dioxide (United Nations Environment Programme, 2009a). When oxygen is absent, bacteria produce methane, which is another common GHG (United Nations Environment Programme, 2009a). However, the amount of greenhouse gases in the atmosphere is increasing because of human activities...
(United Nations Environment Programme & GRID-Arendal, 2002). Since the mid 18th century, the advent of the Industrial Revolution, massive use of wood, charcoal, coal, oil and gas, along with the change of land use, the concentrations of GHGs in the earth’s atmosphere has increased (United Nations Environment Programme, 2009a). The use of artificial fertilizers in the late 19th century also has released large amounts of another GHG, nitrous oxide into the atmosphere (United Nations Environment Programme, 2009a). Since the 1920s, there were a range of GHGs that have been caused by industry and some of these GHGs are considered to be very powerful, for instance refrigeration and fire suppression (United Nations Environment Programme, 2010b).

2.5.12 The impact of global warming on GHG emissions (16)
The impact of GHG emissions on global warming has been discussed in last section. On the other hand, as a result of GHG emission, global warming can also further accelerate GHG emissions (United Nations Environment Programme, 2009a, p. 19). This is due to the potential release of CO₂ and methane that are currently frozen in Arctic soils (United Nations Environment Programme, 2009a, p. 19). Moreover, a talik (An unfrozen section of ground found above, below, or within a layer of discontinuous permafrost) could be produced from the rapid soil thaw, which is a layer of permanently unfrozen soil sandwiched between the perennially frozen layer below and the seasonally frozen layer above, which in turn creates a more faster heat build-up in the soil, thus in a long term, accelerating thaw and release of CO₂ (Johnanson & Fu, 2009; Jones, Lowe, Liddicoat, & Betts, 2009; Lawrence, Slater, Tomas, Holland, & Deser, 2008; Mars & Houseknecht, 2007; Serreze, Holland, & Stroeve, 2007; United Nations Environment Programme, 2008).

2.5.13 Global warming to climate change (17)
Climate change is (National Oceanic and Atmospheric Administration, 2007):

“...a long-term shift in the statistics of the weather (including its averages). For example, it could show up as a change in climate normals (expected average values for temperature and precipitation) for a given place and time of year, from one decade to the next.” (p. 1).

The change of climate is a natural part of the earth’s variability, which can be affected by a myriad of drivers that operate over weeks and over geological eras (National Oceanic and Atmospheric Administration, 2007; United Nations Environment Programme, 2009a). Average temperature changes in a long-term and surface cover are dependent on orbital forcing, solar output variations, volcanic activity, freshwater pulses and the relative positions of oceans and continents, among other factors (United Nations Environment Programme, 2008, p. 4). However, human beings have also induced changes to climate that contributed to global warming. In The Third Assessment Report of the Intergovernmental Panel on Climate Change, it was mentioned that an increasing body of observations has given a collective picture of a warming world and that other changes in the climate system
have occurred (Intergovernmental Panel on Climate Change, 2001). In the fourth assessment report, it has been concluded that the observed increase of anthropogenic greenhouse gases concentrations is very likely to have been caused by the global average temperature increase since the mid-20th century (Intergovernmental Panel on Climate Change, 2007b). A warming planet leads to climate change by affecting weather in various ways, such as the increase rate of extreme weather events, ocean current change, and monsoon disruptions (Shah, 2011; J. B. Smith et al., 2009; United Nations Environment Programme, 2009a).

2.5.14 Global warming to economy (18)
Due to the rise of sea level and melting of sea ice caused by global warming, particularly in the Arctic, this has lead to the accessibility of new shipping routes (World Trade Organization & United Nations Environment Programme, 2009, p. 12). This would have significant impacts on global transportation and resources exploitation such as fossil fuels resources (World Trade Organization & United Nations Environment Programme, 2009, p. 12). For instance, in 2007, the shortest shipping route between the Pacific and the Atlantic – The Northwest Passage, was ice free for navigation for the first time in history (Cressey, 2007). Due to the gradual increase of global temperature, the navigation duration for the Northern Sea Route is expected to be increased in the coming decades (Milner, 2005). This has already heightened attention from many countries and led to discussions on sovereignty over these routes, off-shore developments and seabed resources (Milner, 2005). Furthermore, the opening of new navigable passages and Arctic sea ice decline will also have significant impacts on commercial fishing, tourism, and hunting of marine wildlife resources (World Trade Organization & United Nations Environment Programme, 2009, pp. 12-13).

2.5.15 The impact of climate change on natural disasters (19)
Climate change is happening, and whilst there is controversy about climate change there is a body of evidence to substantiate this (United Nations Environment Programme, 2009a, p. ii). Global climate change can lead to serious consequences such as frequent and intense natural disasters such as floods, droughts, storms, heavy precipitation, as well as ecosystem degradation (United Nations Environment Programme, 2009b). Moreover, these natural disasters are becoming more severe due to the warming of the global climate system (Intergovernmental Panel on Climate Change, 2007b).
Figure 9 shows number of natural disasters in the world, 1940-2008. Sources: The OFDA/CRED International Disaster Database: www.em-dat.net and “EM-DAT: The OFDA/CRED International Disaster Database: www.EMDAT.be — Université Catholique de Louvain — Brussels — Belgium”

Figure 16 shows the increase in the occurrence of natural disasters such as drought, extreme temperature, floods, wildfires and storms from 1940 to 2008 (Intergovernmental Panel on Climate Change, 2007b). As shown in Figure 16, since 1990, there has been the highest rate of increase of natural disasters. Although this may not be completely attributable to climate change, the increase in the intensity and frequency of climate-related disasters does correspond to a rise in the earth’s temperature together with a continuous increase in greenhouse gas emissions (Intergovernmental Panel on Climate Change, 2007b).

Climate change also contributes to ecosystem degradation and causes disasters to the ecosystem. Climate change affects the function and structure of terrestrial, marine and fresh water ecosystems and is likely to lead to the extinction of 20%-30% species (United Nations Environment Programme, 2009b). The IPCC Fourth Assessment Report pointed out that:

“The resilience of many ecosystems is likely to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g. land-use change, pollution, over-exploitation of resources) (high confidence).” (Intergovernmental Panel on Climate Change, 2007a, p. 213)

2.5.16 Climate change to ecosystem (20)
Climate change creates significant risks on ecosystem, causing irreversible loss of unique and threatened systems, include endangered species, coral reefs, biodiversity hotspots,
unique ecosystems, unique ecosystems and indigenous communities (J. B. Smith et al., 2009).

In marine ecosystem, sea level rise lead to the increase of extreme sea-level events such as storm surges, causing severity of flooding in low-lying areas, beaches erosion and damage to the environment, including inter-tidal zones and wetlands, and mangroves, with significant impacts on ecosystem functions and biodiversity (United Nations Environment Programme, 2009a, p. 27). Ocean acidification is another issue, caused by the increase of CO$_2$ concentration in the atmosphere, increasing the amount of anthropogenic CO$_2$ that are absorbed by oceans, which in turn leads to altering the chemistry of the global ocean fundamentally. This happens by “...acidifying the top 2,000 meter layer of the oceans’ waters and thus shrinking the total amount of ocean habitat where organisms that incorporate calcium carbonate (CaCO$_3$) into their shells and skeletons can thrive (United Nations Environment Programme, 2009a, p. 29).” A wide range of marine organisms and the related food webs may be harmed by ongoing ocean acidification, gradually degrading the entire marine ecosystem (United Nations Environment Programme, 2009a, p. 30).

Compare to marine ecosystem, terrestrial ecosystem biosphere shows strong inertia in its response to climate change (United Nations Environment Programme, 2009a, p. 37). Terrestrial ecosystems can be committed to a change over a long period of time before any response is observable. For instance, if the global mean temperature rise of about 2 °C, there will be a risk of significant loss of forest cover in Amazonia rises rapidly (United Nations Environment Programme, 2009a, p. 37). Over the last century, increase in temperature have clearly linked to change in species’ distributions, and it is expected that a larger range shifts can happen in the 21st century due to the projected future climatic change (United Nations Environment Programme, 2009a, p. 37). These changes in turn will change the functioning of ecosystems and ecological communities (United Nations Environment Programme, 2009a, p. 37).

2.5.17 Pollution and ecosystem (21)

E-waste pollutions affect ecosystem in various ways. As showed in Figure 17, dumped materials that contains heavy metals and brominated and chlorinated flame retardants can leach and affect soil and water and be taken up by biota (Sepúlveda et al., 2010). Moreover, some inadequate recycling activities such as burning e-waste, will produce chlorinated and brominates dioxins and furans (PNDD/Fs and PCDD/Fs), and mixed halogenated compounds (Sepúlveda et al., 2010). They can be emitted into atmosphere and tend to accumulate in organic rich media (Gaidajis, Angelakoglou, & Aktsoglou, 2010; Sepúlveda et al., 2010). In addition, even through at the end of the recycle process, the effluents from mercury and cyanide can leach through the soil and water, and form organic and inorganic complexes within soils (Sepúlveda et al., 2010).
2.5.18 Ecosystem and human (22)
European Communities (2008c) have pointed out in their report *The Economics of Ecosystems & Biodiversity* that: “The well-being of every human population in the world is fundamentally and directly dependent on ecosystem services. (p. 12)” Ecosystems with biodiversity are essential to mankind by providing a range of services including: freshwater, food, habitat, carbon sequestration, flood control, soil management and erosion control, waste decomposition, pollination services, climate regulation, and groundwater recharge and storage (Shaikh, 2010; United Nations Environment Programme, 2010a). They also provide sinks for our waste and are source of life-saving drugs (European Communities, 2008c). The development of human has also shaped by the environment and this connection has strong cultural, social and aesthetic significant (European Communities, 2008c). However, currently the health of the ecosystems is under severe pressures due to climate change, biodiversity loss and resource demands by people (United Nations Environment Programme, 2010a). Climate change has brought a further substantial risk to the health of ecosystems thus their abilities in providing ecosystem services are reduced, whilst the population of human and demand for natural resources are increasing rapidly (United Nations Environment Programme, 2010a).

2.5.19 Ecosystem and economy (23)
European Communities (2008c) have also pointed out in their report *The Economics of Ecosystems & Biodiversity* that: “There is no economies without environments, but there are environments without economies. (p. 13)” Ecosystems can protect economy investment by providing goods and services that contain significant economic values, for example, green...
infrastructure and natural capital (Shaikh, 2010). Ecosystems are also a source of natural resources, such as food, fish and forest products (Shaikh, 2010). Furthermore, green spaces also have valuable economic potential, such as tourism, recreation and aesthetics. The relationship between ecosystems and the economy have been showed in figure 18, which contains four elements: human actions (policies), ecosystem structure and function, ecosystem goods and services, and values (National Research Council of the National Academies, 2004). Human actions affect the structure and function of an ecosystem, and ecosystem structure and function is translated to ecosystem goods and services by given the ecological production function (National Research Council of the National Academies, 2004). The translation from ecosystem goods and services to value is given by an economic valuation function (National Research Council of the National Academies, 2004). The ecosystem structure and function can also be translated to values directly by humans, for instance an existing redwood forest can be valued by people’s own rights without considering the services, functions, or goods that they may provide (National Research Council of the National Academies, 2004).

Figure 18: Components of Ecosystem Valuation

2.5.20 The impact of ecosystem on natural disasters (24)
Natural disasters, such as floods and landslides are threatening the lives of millions of people (International Union for Conservation of Nature, 2010). The ongoing ecosystem degradation is exacerbating ecosystem vulnerability and the frequency of extreme weather events has increased because of this (International Union for Conservation of Nature, 2010). The function of healthy ecosystems (such as forests, wetlands and coastal areas) is to provide buffers for extreme events, especially for people whose lives rely on natural resources and physical security (International Union for Conservation of Nature, 2010). The International Union for Conservation of Nature (2010) points out five reasons why ecosystems matter to disaster risk reduction, which are:

- Ecosystems support human well-being that enables people to cope with, withstand, and recover from natural disasters
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- Ecosystems provide cost-effective natural buffers against the impacts of climate change and hazard events
- Resource degradation is linked to disaster risk. For instance, degraded ecosystems are unable to support communities and provide the benefits to reduce their vulnerability to disasters
- Healthy ecosystems with diversity are more robust to extreme weather events
- Ecosystem degradation exacerbating climate change impacted disasters by reduces the ability of natural systems to sequester carbon.

2.5.21 Green ICT strategies and polices (25, 26, 27, 28, 29)
Enhancing resource management, tackling global warming, and improving environmental performance are three main challenges which must be addressed urgently (Organization for Economic Co-operation and Development, 2009e). The environmental performance (it is approximately account for 2-3% of the global GHG emissions (Organization for Economic Cooperation and Development, 2010a)) of information and communication technology (ICT) industry needs to be further improved, whilst the applications of ICT have significant potential to increase efficiency and performance across the society and economy (Organization for Economic Co-operation and Development, 2009e). In order to address environmental challenges, organizations and governments have developed a range of initiatives and programmes on ICT and the environment, in particular, on energy use and global warming (Organization for Economic Co-operation and Development, 2009e). Some programmes conducted by governments also focus on the national targets, such as the Green IT initiatives in Japan (Taketani, 2011), Denmark’s Green IT action plan (Denmark Ministry of Science Technology and Innovation, 2008), and Germany’s “Germany: Green IT pioneer” action plan (Germany Federal Ministry of Economics and Technology, 2008). Relatively, organizations and business associations’ have also developed initiatives on Green ICT, which mainly focus on the reduction of energy costs and the demonstration of corporate social responsibility (Organization for Economic Co-operation and Development, 2009e).

The Organization for Economic Co-operation and Development (2009e) has conducted a survey which analysed 92 government programmes and business initiatives in the European Commission and 22 OECD countries (Organization for Economic Co-operation and Development, 2009e). The result shows that there are 50 of these countries that have been promoted by governments while in the other countries (42) these have been developed by the business organizations (Organization for Economic Co-operation and Development, 2009e). The majority of these initiatives have been conducted internationally (Organization for Economic Co-operation and Development, 2009e). For the use of Green ICT in economic and social performance improvements, there is only one third of the programmes and initiatives focused on these areas, which are actually the majority potential of Green ICT for improving environmental performance, for instance, smart grids, logistics, and urban systems (Organization for Economic Co-operation and Development, 2009e). The result of
this survey also shows that close to two thirds of government programmes and business initiatives concentrate on the reduction of energy consumption and carbon dioxide emissions during the ICT use phase (Organization for Economic Co-operation and Development, 2009e). Around one quarter of these programmes target these areas: the reduction of environmental impacts of ICT disposal, and the use of ICT applications to reduce energy consumption and carbon dioxide emission during distribution and use of non-ICT goods (Organization for Economic Co-operation and Development, 2009e). However, for the rest of these programmes, environmental impacts such as land use, water use, and biodiversity, have been rarely targeted, despite ICT’ impacts (e.g. the impact of dematerialisation on land use, water consumed during ICT production) (Organization for Economic Co-operation and Development, 2009e).

2.5.21.1 Governments’ Green ICT strategies and policies (25, 27, 28)

According to the Organization for Economic and Co-operation and Development (2009e)’s survey for assessing 92 Green ICT strategies and policies across its 22 member countries, the Green ICT strategies and policies of governments cover a range of impacts of ICT on the environment:

Figure 19: Number of Times Environmental Impact Categories has been Targeted by Governments

![Graph](Organization for Economic Co-operation and Development, 2009e)

Figure 19 shows “energy use” is the highest environmental impact of ICT, which has been targeted by most governments’ policies and programmes, followed by “global warming” and “toxicity”. On the other hand, “ozone layer depletion” is the area that has not been targeted, and “water use” and “biodiversity” are rarely targeted.

There are many governments that have realised the importance of adding ICTs to their strategies for tackling environmental problems and the number are increasing (Organization for Economic Co-operation and Development, 2009e). However, although these policies and programmes often focus on some common targets and points, in terms of administrating these policies and programmes, as well as the quality of evaluation and assessment, there are fundamental differences between them (Organization for Economic Co-operation and Development, 2009e). Governments such as United States, Japan and Denmark establish
their administration centrally, in which their policies and programmes are developed and conducted by central government bodies, for example US Department of Energy (DOE), Japan Ministry of Economy, Trade and Industry (METI), and Denmark Ministry of Economy (Denmark Ministry of Science Technology and Innovation, 2008; Myoken, 2008; Scheihing, 2009; Taketani, 2011). In United Kingdom, instead of setting centralised management, governmental programmes are more being organised by local administrations, and departments, while being coordinated by a national board (Organization for Economic Co-operation and Development, 2009e). For example in the United Kingdom, the application of Green ICT is carried out by each government department, with the coordination from the Chief Information Officer Council by an established government-wide Green ICT strategy (UK Cabinet Office, 2008). Furthermore, some intergovernmental bodies such as Asia-Pacific Economic Cooperation (APEC) and the European Commission (EC) conduct and organise Green ICT policies and programmes in forms of intergovernmental cooperation, which APEC provides information about energy efficiency standards in member governments through the “APEC Energy Standard Information System” (Schneider, 2010) and EC has formulated one of these policies and programmes in its Communication (Commission of the European Communities, 2008).

From a different perspective, governments’ Green ICT policies can be a single policy, one example of this is the “Minimum Energy Performance Standards (MEPS)” adopted by Australia and New Zealand governments, which contains mandatory eco standards enforced by the legislation (Australian Department of Climate Change and Energy Efficiency, 2010; New Zealand Energy Efficiency and Conservation Authority, 2010). Several focus areas with multiple policies, such as Denmark’s “Action Plan for Green IT”, which have two sets policies targeting “Greener IT use” and “IT solutions for a sustainable future” (Denmark Ministry of Science Technology and Innovation, 2008) is also an existing strategy.

There is a range of domains governments’ ICT and environment policies can cover, that include Research and Development, ICT diffusion, education and awareness, and Green ICT related skills. This is discussed in the following sections.

2.5.21.1.1 Stimulating Research and Development (R&D) and innovation

It is common that many governments have adopted programmes to increase R&D for Green ICT (Organization for Economic Co-operation and Development, 2009e). There are two main areas for these R&D programme focus, which are energy efficient ICTs, and the applications of ICTs in order to increase energy efficiency outside of the ICT sector (Organization for Economic Co-operation and Development, 2009e). For instance, in Korea, the Korea Communications Commissions has conducted research on Green ICT applications such as smart ICTs (Organization for Economic Co-operation and Development, 2009e). Whilst in Japan, a Green IT project has been promoted and established as Japan’s Green IT initiative, in which industry and academia are participating in this initiative (Myoken, 2008). This project is promoting high energy efficient ICTs and focuses on three research areas, which
include: the energy efficiency of network components, data centre energy consumption reduction, and energy consumption reduction for displays (Myoken, 2008).

2.5.21.1.1 Promoting R&D
Similarly, some governments carried out R&D programmes for the energy efficiency across other industries and households through intelligent applications of ICT (Organization for Economic Co-operation and Development, 2009e). Demark’s government has investigated DKK 36 million as the fund for supporting Green IT, e-government, and pervasive computing research, which is promoting Green IT research as the contributor to a greener society (Denmark Ministry of Science Technology and Innovation, 2008). This fund also supports the R&D on energy efficiency hardware and tele-working and tele-conferencing software technologies (Denmark Ministry of Science Technology and Innovation, 2008).

2.5.21.1.2 Green ICT Procurement by government
As one of the largest purchasers of ICT products and services, governments in many countries are playing significant roles (Organization for Economic Co-operation and Development, 2009e). By conducting large procurement with environmental requirements, governments can reduce the negative environmental impact of their own ICT, and also enable competition and innovation among ICT providers (Organization for Economic Co-operation and Development, 2009e). For example, The UK government’s Green ICT strategy on procurement is to purchase ICTs according to their specification of environmental criteria, which is developed and supported by the Centre of Expertise in Sustainable Procurement of the Office of Government Commerce (OGC) (Organization for Economic Co-operation and Development, 2009e). In Finland, environmental criteria have been added into the tendering procedures and framework agreements, which have been developed by both the Finnish Environment Institute and its procurement unit – Hansel Ltd. Furthermore, the Austrian government has added IT equipment into the list of five priority product groups and set quantitative and qualitative objectives to environmentally friendly purchases (Organization for Economic Co-operation and Development, 2009e).

2.5.21.1.3 Support innovation
For innovation support, there are a number of governments stimulating innovation directly among firms, such as establishing clusters and innovation networks for firms and provide financial and business support services (Organization for Economic Co-operation and Development, 2009e). For example, the Japanese government has formed the Green IT Promotion Council, to support cooperation between government, industry experts and academia (Taketani, 2011). In another example, the European Communities has developed the Competitiveness and Innovation Framework Programme (CIP), of which Intelligent Energy Europe (IEE) is a sub-programme (European Communities, 2011). This sub-programme supports innovation project through funding on topics such as power efficiency, renewable and new energy sources, with a clear target on small and medium sized enterprises. Furthermore, in the “Germany: Green IT Pioneer” action plan (Germany Federal
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Ministry of Economics and Technology, 2008), the German government has also placed a high emphasis on supporting cooperation between companies and company clusters, for instance the e-energy model project, a number of research institutes and several local firms are selected to establish cooperation (Germany Federal Ministry of Economics and Technology, 2009).

2.5.21.1.4 Internationalisation of R&D and innovation

Literature shows that the R&D and innovation of Green ICT can be conducted both nationally and internationally. Some R&D and innovation programmes are promoted internationally by governments. For example, international conferences, meetings and workshops can be held and provide support for knowledge exchange between governments, industries and academia. Governments can also promote the internationalisation of R&D and innovation on ICT and the environment through promoting cooperation with international organizations.

In May 2009, the High-level OECD Conference on ICTs, the environment and climate change in Denmark was hosted by Danish Ministry of Science, Technology and Innovation, which was held as a preparation for and contribute to the United Nations Climate Change Conference in Copenhagen (Organization for Economic Co-operation and Development, 2009a). Moreover, several international conferences have been hosted by Japanese and Danish governments on Green ICT. For instance, the Danish government and the Organization for Economic and Co-operation and Development hosted the Workshop on ICTs and Environmental Challenges in 2008, Copenhagen, where 100 participants attended from a range of sectors, including: government officers, industry experts, scientists, international organization representatives and civil society and business representatives (Danish National IT and Telecom Agency & Organisation for Economic Co-operation and Development, 2008). The Japanese government also hosted the “Green IT International Symposium”, in 2008, 2009 and 2010, in which government officers, international firm representatives presented and discussed their efforts and experiences about Green ICT (Japan Green IT Promotion Council, 2011). For the promotion of cooperation for R&D and innovation with international organizations, some governments have established cooperated relationships with national or international institutions (Organization for Economic Co-operation and Development, 2009e). For instance, the Portuguese government is cooperating with the Massachusetts Institute of Technology (MIT) on postgraduate education and R&D programmes including Green ICT (Roos, 2008).

2.5.21.1.2 Increasing Green ICT applications and diffusion (28)

The largest group of government policies and programmes on ICT and the environment is to increase the diffusion of both Green ICTs and Green ICT applications (Organization for Economic Co-operation and Development, 2009e). Governments are encouraging and promoting the use of Green ICTs and its applications among industries, business and households, applying Green ICT in public administration and being a lead user for Green ICTs,
as well as developing and promoting eco-standards and labels (Organization for Economic Co-operation and Development, 2009e).

2.5.21.1.2.1 Green ICT diffusion to business
The application of Green ICT in business use is a major area with which governments are concerned. Many governments have developed strategies and policies to encourage the use of Green ICT among business, which include demonstrations for best practices of the use of Green ICT, developing and providing measuring tools for energy costs (Organization for Economic Co-operation and Development, 2009e). By implementing these policies and strategies, transparency can be improved which companies are facing during their path to Green ICT (Organization for Economic Co-operation and Development, 2009e). For example, in Denmark’s Green IT action plan, the government demonstrated the best practices in Green IT, and shared the information from the experience of Danish companies in the use of Green ICT (Denmark Ministry of Science Technology and Innovation, 2008). In increasing the transparency of energy consumption of IT equipment, some governments have developed and are providing energy measurement tools such as eco-labels, for instance, Energy Star (U.S. Environmental Protection Agency & U.S. Department of Energy, 2009), EU Eco-Label (European Communities, 2006) and The Blue Angel Eco-Label (German Federal Environment Agency, 2009). Furthermore, some governments have legislated for the use of Green ICT or have encouraged organizations to add the use of Green ICT into their Code of Conduct (Organization for Economic Co-operation and Development, 2009e). For instance, the “EU Code of Conduct for data centres”, sets the goals for energy consumption and provides standards for measurement for data centre providers (European Communities, 2008a). The “EU Code of Conduct for Broadband equipment”, is formulated to reduce energy consumption of broadband equipment (European Communities, 2008b). However, there are relatively few companies that have signed, despite these policies providing information about best practices and standards for non-signatory companies (Organization for Economic Co-operation and Development, 2009e).

2.5.21.1.2.2 Acting as lead user
Governments can apply Green ICT within public administration, by doing this, they can enable the reduction of environmental impact of their own ICTs, thus acting as a lead user to encourage Green ICT usage within the private sector (Organization for Economic Co-operation and Development, 2009e). For example, in Denmark’s “Action Plan for Green IT”, it has been mentioned that in order to reduce energy consumption by 10%, the Danish government is undertaking measures such as arranging priorities for the use of ICT including laptops and thin clients (Denmark Ministry of Science Technology and Innovation, 2008). Moreover, the Danish government has also organized energy saving competitions between departments (Denmark Ministry of Science Technology and Innovation, 2008).
2.5.21.1.2.3 The application of Green ICT in individuals and households

Most governments (participants of OECD’s survey) have a good awareness about the significant contribution of ICTs in carbon dioxide emission reduction and energy saving in household (Organization for Economic Co-operation and Development, 2009e). However for many governments, the diffusion of Green ICT applications to individuals and households is still at an experimental level, which monitoring and evaluation processes are established (Organization for Economic Co-operation and Development, 2009e). An example of this is the “Solar Cities Program” in Australia (Marshall, 2010), a trial project that largely applies distributed solar metering. ICT in this project was used in areas of energy efficiency improvement, smart metering and load management, and cost-reflective pricing (Australian Government, 2009; Marshall, 2010). For households, smart meters have been installed to monitor and plan energy consumption as well as for billing (Australian Government, 2009).

2.5.21.1.2.4 Change of Organizations

ICT applications can help organizations reduce their environmental impact by moving governments and businesses activities to the Internet (e-commerce, e-government) and enabling efficient way of collaboration (tele-working, tele-conference) (Organization for Economic Co-operation and Development, 2009e). However, this area of Green ICT application is rarely adopted by governments’ policies nowadays because of many of them have already implemented it (Organization for Economic Co-operation and Development, 2009e). For example, in the Danish government and in the UK, both governments are promoting tele-working for organizations, while the Danish government is also focusing on e-government and the UK government is focusing on tele-conferencing (Denmark Ministry of Science Technology and Innovation, 2008; Organization for Economic Co-operation and Development, 2009e).

2.5.21.1.3 Promoting awareness and environmental-related ICT skills (26, 27)

In order to use ICT applications to reduce the environmental impact of ICT, people who have both environmental knowledge and ICT-related skills are in high demand by governments and industries (Organization for Economic Co-operation and Development, 2009e). Moreover, using ICT applications also requires a level of awareness about the implications between the environment and personal behaviour (Organization for Economic Co-operation and Development, 2009e). This promotes environmental-related ICT skills and education, and increases public awareness about ICT and its impacts on the environment, which are highly targeted on governments’ policies and strategies (Organization for Economic Co-operation and Development, 2009e).

2.5.21.1.3.1 Educating users and consumers

The behaviour patterns of users need to change in order to cooperate with smart ICT solutions such as smart homes, because even although power efficiency has been increased, without a level of awareness, people may continue to waste energy (Organization for Economic Co-operation and Development, 2009e). Thus, it is necessary to provide education
for ICT users and consumers and this is an important element for governments’ Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009b).

For instance, in Denmark’s Green IT Action Plan, young people have been identified as the largest group of private ICT users and consumers (Denmark Ministry of Science Technology and Innovation, 2008). It is also suggested that social networking sites and online computer games are two important platforms that can be used as tools to introduce and educate young people about ICT and the environment (Denmark Ministry of Science Technology and Innovation, 2008). Another example, the “Green IT initiative” in Japan, is targeting increasing public’s environmental awareness through measuring and visualising the net impact of ICTs on the environment (Myoken, 2008).

2.5.21.1.3.2 The demand of energy management skills and expertise
Currently, many companies are facing problems of insufficient energy management skills and lack of expertise while they are adopting Green ICTs (Marthinez & Bahloul, 2008). In addition, some governments have started to provide relevant Green ICT training for managers and their employees (Organization for Economic Co-operation and Development, 2009e). The US Department of Energy has developed a training programmes called “Save Energy Now Initiative”, which aims at providing training to managers and improving their energy management skills, by providing best practises and improvements in energy efficiency technologies regularly (U.S. Department of Energy, 2010; Wright et al., 2010).

2.5.21.2 Industry Associations’ Green ICT initiatives (28, 29)
According to OECD’s (Organization for Economic Co-operation and Development, 2009e) survey, as shown in figure 20, industry association’s Green ICT initiatives cover a range of impacts of ICT on the environment:

Figure 20: Number of Times Environmental Impact Categories Have been Targeted by Industry Associations

(Organization for Economic Co-operation and Development, 2009e)
In terms of Green ICT, “energy use” is the category that has been mostly targeted by industry associations followed by “global warming”. On the other hand, areas such as “water use”, “ozone layer depletion”, and “biodiversity” have not been targeted.

2.5.2.1.2 Different types of industry associations
Industry associations and organizations play a significant role in reducing the environmental impact (Organization for Economic Co-operation and Development, 2009e). Industry associations and organizations are major developers of Green ICT initiatives and they are different in terms of the programmes they undertake, objectives and types of members (Organization for Economic Co-operation and Development, 2009e). Three types of different industry associations have been identified, including sector specific, cross-sector and standards associations (Organization for Economic Co-operation and Development, 2009e).

The sector specific associations consist of companies within a specific sector. For instance, the “European Telecommunications Network Operators’ Association” (ETNO) (The European Telecommunications Network Operators’ Association, 2011), “Consumer Electronics Association” (CEA) (Consumer Electronic Association, 2010), and the “Silicon Valley Leadership Group” (Silicon Valley Leadership Group, 2011). These types of industry associations can be national such as CEA or international like ETNO, or working closely with government like “Silicon Valley Leadership Association” (Consumer Electronic Association, 2010; Silicon Valley Leadership Group, 2011; The European Telecommunications Network Operators’ Association, 2011).

The cross-sector industry associations are not sector specific (Organization for Economic Co-operation and Development, 2009e), but rather, they usually operate globally (Organization for Economic Co-operation and Development, 2009e). For this kind of industry association, companies and organisations come from different sectors and their major objective is to come together to develop and cooperate in their Green ICT initiatives (Organization for Economic Co-operation and Development, 2009e), such as “Global e-Sustainability Initiative” (GeSI) (Global e-Sustainability Initiative, 2009), “Climate Savers Computing Initiatives” (CSCI) (Hejmanowski & Friend, 2010), and the “Green Grid” (V. Smith, 2009).

The last type of industry associations are aiming to promote standardisations among members, for instance, the “Institute of Electrical and Electronics Engineers” (IEEE), “European Telecommunications Standards Institute” (ETSI), and the “Alliance for Telecommunications Industry Solutions” (ATIS) (Organization for Economic Co-operation and Development, 2009e).

2.5.2.1.2 Promoting R&D and Innovation
As two increasingly important purchase criteria, material and energy efficiency have become two main factors that encourage ICT producers to increase material and energy efficiency of their products and services, as well as governments’ regulation and the social responsibilities (Organization for Economic Co-operation and Development, 2009e).
2.5.21.2.2.1 Support for innovation
Industry associations frequently conduct activities about innovation support, aiming at stimulating innovation among their members, enhancing cooperation and share knowledge and information among their members (Organization for Economic Co-operation and Development, 2009e). One example is the “Energy Efficiency Inter-Operator Collaboration Group” (EE IOCG) (Alliance for Telecommunication Industry Solutions, 2009, p. 22). It supports information share on “energy critical issues” of networks and ICT (Alliance for Telecommunication Industry Solutions, 2009, p. 22). Another example, the “Consumer Electronics Energy Efficiency Group” established by Intellect, helps its members to identify the best low carbon technologies and encourage their development (Intellect, 2009).

2.5.21.2.2 Designing resource-efficient ICT products
A critical aspect of material and energy efficiency for ICT goods production is the design stage, which includes R&D on material and energy efficient ICTs and ICT components. For instance, the “European Information and Communication Technology Industry Association” (EICTA) is promoting to integrate environmental considerations at the product design stage so that all relevant negative potential environmental impacts can be reduced over the entire lifecycle (European Information and Communication Technology Industry Association, 2007). Moreover, there are criteria about the level of energy consumption for the “Climate Savers Computing Initiatives” require members to commit to “develop products that meet or exceed the Initiative’s Program Criteria” (Intel, 2007). For computer equipments such as laptops and workstations, the criteria are the same as the Energy Star 4.0 specifications (Organization for Economic Co-operation and Development, 2009e).

2.5.21.2.3 Increase Green ICT diffusion and applications (28)
With the rising awareness of industry associations on the potential of saving energy costs throughout their sectors enabled by Green ICT, more and more industry associations are promoting the diffusion and use on both Green ICT and its applications (Organization for Economic Co-operation and Development, 2009e). This includes Green ICT labels and standards, procurement for Green ICT, and applications of Green ICT such as energy saving tools, “tele-“applications for travelling reductions (Organization for Economic Co-operation and Development, 2009e).

2.5.21.2.3.1 Standards and labels for Green ICT
One strong obstacle to Green ICT is insufficient standardised instruments for the evaluation and monitoring of energy cost of ICTs (Organization for Economic Co-operation and Development, 2009e). Examples of these instruments include accounting tools, measurement, and eco-labels, which used for indicate material and energy efficiency of ICTs (e.g. the Electronic Product Environmental Assessment Tool (EPEAT) (Northeast Recycling Council, 2010), 80-Plus (Ecos Consulting, 2005), PC Green Label (PC3R Promotion Association, 2011), and TCO Certification (TCO Development, 2010). Some industry associations are promoting standards and labels for Green ICT (Organization for Economic
Co-operation and Development, 2009e). This includes tools of measurement and accounting, as well as guidelines used for improving the accountability of energy costs (Organization for Economic Co-operation and Development, 2009e). For example, a reporting guideline is being developed by GeSI under its multi-stakeholder task force (Organization for Economic Co-operation and Development, 2009e).

2.5.21.2.3.2 Energy efficient data centres
Data centres have been identified as one of the most energy-consumed ICT applications (Organization for Economic Co-operation and Development, 2009e). It is expected that increasing amount of data will be used in the future due to the dramatically increase of the quantity of data to be stored and managed (Organization for Economic Co-operation and Development, 2009e). Industry associations are promoting the optimisation of cooling systems and power supply within data facilities along with the consolidation of physical servers by applying virtualisation technology (Organization for Economic Co-operation and Development, 2009e). An example is the “Telecommunications Infrastructure Standard for Data Centres of the Telecommunications Industry Association (TIA)”, which developed standards for data centre facilities (ADC KRONE, 2008). These standards include site space and layout, cabling, reliability of tiered and considerations for the environments (ADC KRONE, 2008).

2.5.21.2.3.3 Green ICT procurement
By conducting green procurement, the diffusion of Green ICTs can be supported. Recyclable, reusable, and energy efficient components are the main objective for procurement, thus they can be used for the production of material and energy efficient ICT products (Organization for Economic Co-operation and Development, 2009e). For example, “myGreenElectronics.org”, a website developed by the Consumer Electronics Association (CEA), where ICT goods producers can register their “Green ICT products” for free exposure (Consumer Electronic Association, 2009). The aim for this practise is to support business and households finding and purchasing energy efficient ICT products (Consumer Electronic Association, 2009).

2.5.21.2.3.4 Use of Green ICT among members
A small number of industry associations are encouraging their members to use Green ICTs by themselves, such as applications for power management in order to save energy within their work and daily lives, as well as changing the way of their working through ICT applications such as tele-conferencing and tele-working (Organization for Economic Co-operation and Development, 2009e). One example is that in order to reduce the costs on travelling, ICT Norway is proposing tele-working applications to all its members (Waaler, 2009). Another example is the Climate Savers Computing Initiatives, encouraging all its members to install power management applications into their PCs (Climate Savers Computing Initiative, 2007, p. 8).
2.5.21.2.4 Value chains Optimisation

In order to reduce the environmental footprint of ICT sector, industry associations are also concentrating on the efficiency improvement throughout their value chains, as well as optimising and reducing the energy consumption across their production and distribution networks (Organization for Economic Co-operation and Development, 2009e). For example, the Norwegian Green IT project is focusing on establish networks for joint transportation of goods so that the transport costs can be reduced (Organization for Economic Co-operation and Development, 2009e). Another example, the **Liaison Group of Japanese Electrical and Electronics Industries for Global Warming Prevention** has developed the **Voluntary Action Plan on Global Warming Prevention** (Liaison Group of Japanese Electrical and Electronics Industries for Global Warming Prevention, 2008). It is promoting the improvement of production capacity so that can help reduce carbon dioxide emissions per basic unit of production (Liaison Group of Japanese Electrical and Electronics Industries for Global Warming Prevention, 2008).
2.6 Implication of Level 3 Model

Figure 21: Level 3 Model

1. Reduce GHG emission through smart ICT applications
2. People with skills and awareness in Green ICT support its development
3. ICT support and accelerate economy
4. ICT support communication, increase social awareness, education
5. Market driven
6. Opportunities
7. Technology (ICT)
8. Contribution to economy
9. Ecosystem
10. Negative impact
11. Tackling
12. Global warming
13. Pollution
14. Negative impact
15. Absorb infrared light
16. New shipping routes and exploitation resources in the Arctic
17. Antarctic ice melting, extra green houses gases release from the soil.
18. Green house gases emission
19. Negative impact
20. Negative impact
21. Ecosystem
22. Taking, and providing resources
23. Support
24. Ecosystem degradation creates disaster risks
25. Politics (policies, strategies and legislation)
26. Social Awareness
27. Affect policies and strategies making
28. Social responsibilities guide human’s behaviours
29. Industry participant in the implementation of Green ICT policies and strategies
30. Support
31. Lead to
32. Politics (policies, strategies and legislation)
33. Natural disasters
34. Better handled by remote sensing technology and GIS
35. Human Organizations
36. Negative impact
37. Negative impact
38. Negative impact
As shown in figure 21 there are significant complexities involved in the impacts of Green ICT in model level 3, which reflect that the issues of ICT and the environment is only meaningful when considered systemically instead of segmentally. The construction of this model is started from element “ICT” as a central point, passing through “human world” (organization, economy and society) and scattered across the “external area” – the environment, and linking those elements together and considered as a whole system in related to the impacts of ICT. Through studying this holistic model, many issues and solutions can emerge. Similar to model level 1 and 2 (see figure 2 and 7), there are three groups of ICT’s impact that can be identified from this model: the direct (first) impact, enabled (second) impact and systemic effects. Moreover, some connections between elements show dual-characters, in which they contribute to the issues but are also the source of solutions. Furthermore, systemically, a large number of loops (and sub-systems) can be identified from the level 3 model, which shows that the impact of ICT can be very systemic and most of the impacts can return along loops and affect the starting element.

For instance, in the centre of level 3 model, it shows ICTs can have direct impacts on issues related to the environment through some applications (arrow 9, 10, 1, 2, 11, and 12) such as remote sensing technologies, RFID and Geographical Information Systems (GIS). Whilst, on the other hand, it is also acting as a contributor (arrow 1 and 2) to some environmental issues, such as e-waste that can create pollution, as well as the use of energy inefficient ICT infrastructure that can contribute to significant amount of GHG emissions. In addition, these direct impacts will turn back to and affect the starting elements after interacted with other elements along these loops. In addition, Sub-systems can be identified from this model. In this case, the applications of Green ICT can be used for tackling environmental problems, and the impacts of those applications can eventually return to element “ICT” and affect ICT’s development, and this can happen in both positive and negative ways (e.g. arrow 1-13-22-7 and 11-18-5), this is shown in figure 22 as follow:
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Figure 22: Two Loops in Level 3 Model

Figure 22: Two Loops in Level 3 Model

Layer 1: Direct impact of ICT, numbers with red colour
Layer 2: Enabled impact of ICT, numbers with purple colour
Layer 3: Systemic effect, numbers with brown colour

1. Lead to
2. Opportunities
3. ICT support communication, increase social awareness, education
4. People with skills and awareness in Green ICT support its development
5. Support and accelerate economy
6. Market driven
7. Create and use
8. Contributions to economy
9. Ecosystem degradation creates disaster risks
10. Taking, and providing resources
11. Tackling
12. Lead to
13. Negative impact
14. Aerosol particles block the full effect of GHGs radiative forcing to heat the Earth
15. Absorb infrared light
16. Green house gases emission
17. Global warming
18. New shipping routes and exploitation resources in the Arctic
19. Lead to
20. Negative impact
21. Ecosystems
22. Negative impact
23. Pollution
24. Climate change
25. Politics (policies, strategies and legislation)
26. Social Awareness
27. Industry participant in the implementation of Green ICT policies and strategies
28. Social responsibilities guide human’s behaviours
29. Better handled by remote sensing technology and GIS
30. Neglected impact
Figure 22 shows two selected loops (or sub-systems) as examples in the level 3 model, which have been indicated by green and blue colour. The “green” loop can be defined as a negative impact of ICT. It shows that the e-waste (arrow 1) created by ICT can cause pollution and pollutions can contribute to ecosystem degradation (arrow 13), and then this degradation will put human at serious risks (arrow 22). Finally industries will respond to this and promote the development of Green ICTs in order to tackle ecosystem degradation (arrow 10), as well as reducing e-waste (arrow 1). The “blue” loop seems to be positive. It starts from the application of ICT on tackling global warming (arrow 11) and affects the economy in a positive way by creating new shipping routes in the Arctic area. Eventually, the growth of economy will support the development of the ICT.

In another aspect, like the level 1 model, the level 3 model can also be divided into three layers: direct impact, enabled impact and systemic effects. Since the complexity of the level 3 model is such that the position of the arrows are not closed to each other, thus layers are hard to mark in the figure graphically. However, tables have been developed to indicate and express these layers in the level 3 model. In the figure of level 3 model (figure 22), the number of labels for different layers are distinguished using a different colour, red means arrows that belong to layer 1, purple colour for layer 2, and brown colour for layer 3.

2.6.1 Layer 1 of level 3 model (ICT’s direct impact)
Layer 1 of level 3 model contains impacts that are directly caused by the control element – “ICT”. As shown in table 4, arrows that fall into the direct impact of ICT have been indicated, with elements involved and brief descriptions about the major impacts. This level 3 model is constructed based on the Level 1 and 2 model, thus the direct impacts of ICT (layer 1) can be categorised into three clusters, which are, in terms of Green ICT, the direct impact on economy (arrow 5a), the direct impact on society (arrow 4a and 6), and the direct impact on the environment (arrow 1, 2, 9, 10, 11 and 12).

<table>
<thead>
<tr>
<th>Arrow Number</th>
<th>Elements involved</th>
<th>Major impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICT – Pollution</td>
<td>E-waste causes pollution (Huisman et al., 2007); The applications of Green ICT tackle pollution (Weber, 2009, p. 47).</td>
</tr>
<tr>
<td>2</td>
<td>ICT – GHG emission</td>
<td>Contribute to GHG emission (T-systems, 2010); Green ICT helps reduce GHG emission produced by ICT sector (T-systems, 2010).</td>
</tr>
<tr>
<td>4a</td>
<td>ICT – social awareness</td>
<td>ICT enhance communication so that support to increase social awareness (Hasan et al., 2009; Hasan &amp; Kazlauskas, 2009b); Necessity in educating Green ICT (Organization for Economic Co-operation and Development, 2009a).</td>
</tr>
<tr>
<td>5a</td>
<td>ICT – economic</td>
<td>ICT is about to play an increasingly significant role as a</td>
</tr>
</tbody>
</table>
critical enabler of sustainable and renewed growth of economy (Dutta & Mia, 2010)

Green ICT solutions can support business process by streamlining processes and potentially helping companies to reduce CO2 emission by improving the utilization of resources and allowing them to be shared (T-systems, 2010).

ICTs have been fully applied across climate-related disaster management (Yap, 2011).

ICTs have been widely applied throughout the area of environmental observation, analysis, planning, and management (International Telecommunication Union, 2008a, p. 25).

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ICTs have been widely applied throughout the area of environmental observation, analysis, planning, and management (International Telecommunication Union, 2008a, p. 25).

2.6.2 Layer 2 of level 3 model (ICT’s enabled impact)
Layer 2 of the level 3 model contains the “second-order” impacts enabled by ICT in terms of a “Green” concept. These arrows have no direct connection with the central element – “ICT”. However, connections are established between these arrows, as well as transmitting and distributing the direct impacts from Layer 1 extend further than the external areas. As shown in table 5, arrows that fall into the enabled impacts of ICT have been indicated, with elements involved and brief descriptions about the major impacts. Arrows that belong to this layer can also be categorised into different clusters, which are the economic cluster, social cluster and the environmental cluster. The economic cluster contains arrow 23, 3 and 8; social cluster contains arrow 25, 26, 27, 28, 29 and 8; and environmental cluster: arrow 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24. Since arrow 23 and 8 are bi-directional, they have been categorised twice in different clusters.

Table 5: Model 3, Layer 2

<table>
<thead>
<tr>
<th>Arrow Number</th>
<th>Elements involved</th>
<th>Major impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Economy – GHG emission</td>
<td>Reduce GHG emission through smart ICT applications and dematerialization (The Climate Group &amp; Global e-Sustainability Initiative, 2008).</td>
</tr>
<tr>
<td>8</td>
<td>Organization and economy (bi-directional)</td>
<td>Green ICT is a new growth point of economy and provide organizations opportunities (Mickoleit et al., 2009).</td>
</tr>
<tr>
<td>13</td>
<td>E-waste pollution – human health</td>
<td>These toxic substances could result in a range of human health problems (Swedish Environmental Protection Agency, 2011).</td>
</tr>
<tr>
<td>14</td>
<td>Pollution – global</td>
<td>Aerosol particles work as a “mask”, blocks the full</td>
</tr>
<tr>
<td>Chapter 2: Literature Review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>warming</strong></td>
<td>effect of Greenhouse gases radiative forcing to heat the earth (United Nations Environment Programme, 2009a, p. 10).</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>GHG emission – global warming</td>
<td>Large amount of GHGs trap the infrared radiation from sunlight, so that cause Greenhouse effect (United Nations Environment Programme &amp; GRID-Arendal, 2002).</td>
</tr>
<tr>
<td>16</td>
<td>Global warming – GHG emission</td>
<td>Extra CO₂ and methane can release from the Arctic freezing soils (United Nations Environment Programme, 2009a, p. 19).</td>
</tr>
<tr>
<td>17</td>
<td>Global warming – climate change</td>
<td>A warming planet leads to climate to change in a way of affect weather in various ways, such as the increase rate of extreme weather events, ocean current change, and monsoon disruptions (Shah, 2011; J. B. Smith et al., 2009; United Nations Environment Programme, 2009a).</td>
</tr>
<tr>
<td>18</td>
<td>Global warming – economy</td>
<td>Due to the rise of sea level and melting of sea ice caused by global warming, particularly in arctic, lead to the accessibility of new shipping routes and exploitation of natural resources (World Trade Organization &amp; United Nations Environment Programme, 2009, p. 12).</td>
</tr>
<tr>
<td>19</td>
<td>Climate change – natural disaster</td>
<td>Global climate change can lead to serious consequences such as frequent and intense natural disasters such as floods, droughts, storms, heavy precipitation, as well as ecosystem degradation (United Nations Environment Programme, 2009b).</td>
</tr>
<tr>
<td>20</td>
<td>Climate change – ecosystem</td>
<td>Climate change creates significant risks on ecosystems, causing irreversible loss of unique and threatened systems, include endangered species, coral reefs, biodiversity hotspots, unique ecosystems, unique ecosystems and indigenous communities (J. B. Smith et al., 2009).</td>
</tr>
<tr>
<td>21</td>
<td>E-waste pollution – ecosystem</td>
<td>Toxic to ecosystem, up taken by biota, and contaminate air, water and soil (Sepúlveda et al., 2010).</td>
</tr>
<tr>
<td>22</td>
<td>Ecosystems – human</td>
<td>Ecosystems with biodiversity are essential to human by providing a range of services. (Shaikh, 2010; United Nations Environment Programme, 2010a). They also provide sinks for our waste and are source of life-saving drugs (European Communities, 2008c).</td>
</tr>
<tr>
<td>23</td>
<td>Ecosystem and economy (bi-directional)</td>
<td>Ecosystem can protect economy investment by providing goods and services which contain significant economic values (Shaikh, 2010); ecosystem services are taken as goods (National Research Council of the National Academies, 2004).</td>
</tr>
<tr>
<td>24</td>
<td>Ecosystem – natural disasters</td>
<td>The function of healthy ecosystems (such as forests, wetlands and coastal areas) is to provide buffers to extreme events, especially for people whose lives are rely on natural resources and physical security (International Union for Conservation of Nature,</td>
</tr>
</tbody>
</table>
**Chapter 2: Literature Review**

<table>
<thead>
<tr>
<th>Arrow Number</th>
<th>Elements involved</th>
<th>Major impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Social awareness - environmental problems</td>
<td>Increase social awareness through polices and strategies in terms of Green ICT. Tackling environmental problems through implementing Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009e).</td>
</tr>
<tr>
<td>27 a&amp;b</td>
<td>Government Green ICT policies &amp; strategies and social awareness (bi-directional)</td>
<td>Educating users and customers about ICT and the environment; Training expertise in Green ICT area and response to the large demand of people with such skill (Organization for Economic Co-operation and Development, 2009e).</td>
</tr>
<tr>
<td>28</td>
<td>Organization and social awareness (bi-directional)</td>
<td>Industry associations and business have started working on the increase of social awareness among their members and employees (Organization for Economic Co-operation and Development, 2009e).</td>
</tr>
</tbody>
</table>

*All the impacts are considered in the context of ICT*

### 2.6.3 Layer 3 of level 3 model (systemic effects)

As shown in figure 22, all the possible loops return to the central element “ICT” through these three arrows. These are the last steps of the “impact cycles” for which the impacts of ICT could be identified systemically in the model. As shown in table 6, arrows that fall into the systemic effects of ICT are indicated, with elements involved and briefly descriptions about the major impacts.

**Table 6: Model 3, Layer 3**

<table>
<thead>
<tr>
<th>Arrow Number</th>
<th>Elements involved</th>
<th>Major impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>5b</td>
<td>Economy – ICT</td>
<td>The development of ICT in a “Green / sustainable” direction is strongly driven by market (PricewaterhouseCoopers, 2008, p. 15).</td>
</tr>
<tr>
<td>4b</td>
<td>Social awareness – ICT</td>
<td>Education and training in Green ICT area is the key to assure the supply of ICT-skilled engineers to develop and deploy Green ICT (Organization for Economic Co-operation and Development, 2009a).</td>
</tr>
<tr>
<td>7</td>
<td>Organisations – ICT</td>
<td>Organisations play a critical role in Green ICT research, development, and use (Harmon &amp; Demirkan, 2011; Unhelkar, 2011).</td>
</tr>
</tbody>
</table>
Moreover, there are also many subsystems that can be found from level 3 model, and readers can identify them based on their specific requirements. For instance, the “Organization, Economy and ICT” subsystem:

Figure 23: The “Organization, Economy and ICT” Subsystem

The “Economy, GHG emission, and ICT” subsystem:

Figure 24: The "Economy, GHG Emission, and ICT" Subsystem
As well as the “Organizations, Politics, Social awareness, and ICT” subsystem:

**Figure 25: The “Organizations, Politics, Social Awareness, and ICT” Subsystem**

2.7 **CHAPTER SUMMARY**

In this chapter 2, a holistic study for Green ICT issues is conducted. This includes most of the areas that ICT could impact on in terms of a “Green” concept. Three models are built while reviewing relevant literature, which are Level 1 (figure 4, page 13), 2 (figure 7, page 19) and 3 models (figure 8, page 24). Level 1 model is constructed on a base level, and then more information is added to this base level and forms the level 2 model. Finally, Level 3 model is constructed and proposed base on a more comprehensive review of the literature based on level 1 and 2 models and provides a holistic view on the Green ICT issues. Furthermore, the implications of the three models are also discussed in this chapter. In next chapter, the methodology adopted for this research is discussed.
3  CHAPTER 3: METHODOLOGY

3.1  INTRODUCTION
This chapter provides rationale for the methodology adopted for this research – Soft Systems Methodology (SSM), research questions, the design of the research, the sampling technique, data collection, as well as data analysis methods. It also discusses possible ethical issues that may happen during this research and ways to avoid them, in addition the validity of the modelling method in SSM, as well as the limitations of this research.

3.2  RESEARCH QUESTIONS
The research questions for this research are:

1. What are problems that exist in the implementation of Green ICT strategies in New Zealand for ICT recycling?

2. What are the appropriate solutions (systemically desirable and culturally feasible) for these problems?

3.3  SOFT SYSTEMS THINKING
Scientists and engineers have predominantly used reductionism, thus the principle of analysis of a problem focuses on decomposition and structure that find out how things work (Warwick, 2008). Decomposition, explanation and synthesis are the three aspects on which the process focuses (Warwick, 2008). Whilst, in fact the application of this “scientific method” can be used to undertake certain types of investigation, the desire to explore observed phenomena lead to the evaluation which extend the method beyond the conventional sciences of physics, chemistry and biology into social sciences and psychology (Warwick, 2008). This therefore suggests that researchers may need to question existing modes of thought in order to study the interactions and influences that underpin some phenomena (Warwick, 2008).

However, some researchers contended that: “...system ideas can provide a source of explanation for many kinds of observed phenomena which are beyond the reach of reductionist science (Warwick, 2008, p. 4).” Checkland thinks that systems thinking is an holistic reaction that is quite a different way of thinking than the reductionism of natural science (Warwick, 2008). Checkland’s view has changed the manifestation of systems thinking that studies highly complex issues through a way of thinking about wholes (Warwick, 2008).
Chapter 3: Methodology

Figure 26: The Hard and Soft Systems Stances

Figure 26 clearly outlines the difference between hard systems thinking and soft systems thinking. Hard systems engineers thinking assumes that the perceived world contains “holons (Checkland & Scholes, 2000, p. 22)” (as an alternative name to “system” for the concept of whole) and tackles well-defined problems. On the other hand, soft systems thinking takes the stance that the methodology (enquiry process), can itself be created as a holon (Checkland & Scholes, 2000, p. 22). Thus soft systems thinkers adopt soft systems methodologies to address ill-structured, messy, problem situations (Checkland & Scholes, 2000, p. 22).

3.4 Soft Systems Methodology

Peter Checkland developed an iterative approach known as Soft Systems Methodology (SSM). SSM is developed based on General Systems Theory founded by von Bertalanffy (1981), which “…views everything in the world as part of an open, dynamic, and interconnected system. The various parts of this system interact with on another often in a nonlinear way, to produce a result.” (Morcos & Henshaw, 2009, p. 4).
Chapter 3: Methodology

Thus SSM is:

“...an analytical technique that is based on the concept of systems thinking and tries to understand a given problem domain in different circumstances and across multiple perspectives. It does not define rigid steps to follow but is strategic in its approach by employing a top-down procedure, for example, taking a holistic view of the problem rather than looking immediately at the detailed level.” (N. Williams, Ivins, & Burgess, 2006, p. 3).

The application of SSM is very broad, from small and medium size firms to large corporations, and from organizations in both public and private sectors (Checkland & Poulter, 2010, p. 193). Information technology and information systems are two areas in which SSM has been heavily applied (Checkland & Poulter, 2010, p. 193).

3.4.1 Soft Systems Methodology in software design

Mathiassen, Munk-Madsen, Nielsen and Stage (1991) introduced the use of soft systems thinking in computer software development and introduced a method called “Rapid Systems Modelling”:

“Rapid Systems Modelling combines a set of widely appreciated principles and methods into one coherent framework. The approach taken to design emphasizes learning as in Soft Systems Methodology. Rapid Systems Modelling combines this approach to learning with techniques and tools for modelling and experimenting with systems based on object-oriented thinking and the use of prototypes.” (p. 317).

Furthermore, Kimble (2008) outlined four categories for software design methods, which are formal software design methods, semi formal software design methods, object orientated software design methods, and holistic software design methods, and shown as follow:

Table 7: Software Design Methods Categories

<table>
<thead>
<tr>
<th>Formal software design methods</th>
<th>Examples</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unity, Z, VDN</td>
<td>• Assumes software and program descriptions to be equivalent. For example, both are compete and closed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• By removing any distinction between programs and software, the formal strand seeks to introduce rigor of mathematics into both software and program design.</td>
</tr>
<tr>
<td>Semi formal software design methods</td>
<td>Jackson System Development, Structured Systems Analysis and Design Method</td>
<td>• Strongly linked to program design methods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Assumes the software description is complete but not closed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• These methods focus on controlling the logical flow in the program, which set the programmer free from having to be concerned with implementing any physical details.</td>
</tr>
</tbody>
</table>
### Chapter 3: Methodology

<table>
<thead>
<tr>
<th>Object orientated software design methods</th>
<th>Booch Object Oriented Design, Rational Unified Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Strongly linked to object oriented languages</td>
<td></td>
</tr>
<tr>
<td>• Assumes the software description is closed but not complete.</td>
<td></td>
</tr>
<tr>
<td>• Reality is used as a baseline to free the program designer from concerns about the problems of dealing with physical system’s inaccurate representations.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Holistic software design methods</th>
<th>Soft Systems Methodology, ETHICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Seeks a holistic view of the whole system.</td>
<td></td>
</tr>
<tr>
<td>• Abandons any relationship between program design and software design.</td>
<td></td>
</tr>
<tr>
<td>• Does not assume the software description is complete or closed.</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 shows the four categories of software design methods, and some examples and descriptions of their characteristics. Soft Systems Methodology falls into the fourth category – Holistic software design methods.

In addition, Avison and Fitzgerald (1995) outlined the scope of methodologies in information systems development (Figure 27). The shaded areas show that the methodology covers the phase deeply in detail with specific tools and techniques provided for support (Avison & Fitzgerald, 1995, p. 464). The un-shaded areas indicate that the methodology addresses those areas with less depth and detail. Furthermore, the areas with broken lines means that those areas are only briefly mentioned by the methodology without any procedures, techniques or rules are provided (Avison & Fitzgerald, 1995, p. 464). As shown in this figure, SSM addresses the strategy and analysis phases in detail, and focuses on the feasible and desirable changes in an information system development (Avison & Fitzgerald, 1995, p. 465).

**Figure 27: Scope of Methodologies**

(Avison & Fitzgerald, 1995, p. 465)
3.4.2 The philosophy

Soft Systems Methodology positions itself in the field of interpretivism and particularly in the philosophy of hermeneutics and phenomenology (Mirijamdotter, 1998, p. 12), because of the key idea upon which SSM is developed is interpreting problem situations according to what can be found meaningful (Mirijamdotter, 1998, p. 12). In contrast with positivism, SSM takes the position that values and facts as intertwined and hard to disentangle, positivism, on the other hand, views values and facts as distinct and that scientific knowledge consists only of facts (Mirijamdotter, 1998; Walsham, 1995). Furthermore, Christis (2005) pointed out the contradictions involved in philosophy of SSM between realism and anti-realism as following:

“…we showed the realism that is implicit in and the condition of the possibility of the practice of model building and application of SSM.” (p. 8) And “…it is looking at ‘the philosopher’ in Checkland and his peculiar combination of anti-realism with regard to the things we speak about and realism with regard to the meaning of the words we speak with.” (p. 8)

Thus there is a performative contradiction committed by Checkland: “to do something in your practice and to deny the rationality of what you do in your theory of that practice.” (p. 8)

3.4.3 The conventional seven-stage model of SSM

Figure 28: 7 Stages of the SSM

![Diagram of the seven-stage model of SSM](Checkland & Scholes, 2000, p. 27)
Figure 28 shows the procedure for SSM. The benefit of SSM that can be derived from the use in targeting “soft” issues – “…a systems view is generated that contrasts nicely with the rather more quantitative results-driven and analytical quality assurance processes that are traditionally used to assess the effectiveness of a module. (Warwick, 2008, p. 5)”

As shown in figure 28, there are seven steps that need to be followed:

**Step 1 and 2:** Understand and define the problem situation such as stakeholders and the nature of the processes, and then use rich pictures to express the problem situation (YorkU, 2008). In this step, in order to gain a holistic in-depth understanding of the issues, a holistic literature review (see the literature review chapter) and a survey are conducted. For the literature review, a holistic model is constructed for the comparison and mapping in stage 5. For the survey, there are some key stakeholders that have been defined for these issues: ICT scholar, ICT leasing company in New Zealand, the customer of the leasing company, a government body, and a New Zealand green group ICT spokesperson.

**Step 3:** Choose the way to view the situation and describe the nature of the chosen system (Warwick, 2008; YorkU, 2008). The data that has been gathered from the online survey (and e-mails) is then used for formulating root definitions. Smyth and Checkland use “CATWOE” and suggested that well-formulated root definitions should be prepared by consciously considering the elements. The “CATWOE” is shown in figure 29:

![Figure 29: The CATWOE Mnemonic](Checkland & Scholes, 2000, p. 35)
Figure 29 shows the “CATWOE” mnemonics for the preparation of formulating the data into root definitions. This is the mnemonics that is used in this research. Data collected by the questionnaire will be translated into the form of a “CATWOE”. Then based on “CATWOE”, the root definitions can be developed. It is “a system to do X by Y in order to achieve Z” (Checkland & Scholes, 2000, p. 35) where X means Y, Z is related to the owner’s aims in the longer term, and an arguable connection must be existed which makes Y an appropriate means for doing X (Checkland & Scholes, 2000, p. 35).

**Step 4:** Adequately address each of the root definitions by building the conceptual models of the Holons (YorkU, 2008). In this step, conceptual models are built based on the root definitions that have been formulated from the last step.

**Step 5:** Compare those conceptual models built in Step 4 to the real world expression (step 2) (YorkU, 2008). Compare each model of the stakeholders with the relevant situations in the rich picture of the real world that has been developed in step 2. Checkland indicated that there are four ways of conducting this comparison, which include: “informal discussions; formal questioning; scenario writing based on “operating” the models; and trying to model the real world in the same structure as the conceptual models. (Checkland & Scholes, 2000, p. 43)”. For this research, the researcher will model the real world in the same structure as the conceptual models.

**Step 6:** Identify desirable and feasible improvements for the situation, and develop recommendations for solutions (YorkU, 2008). Based on the results of the analysis from the last step, which have differences between the conceptual models and perceived realities, possible solutions can be suggested. Moreover, SSM allows the identification of solutions that are both systemically desirable and culturally feasible, which means the solution will mitigate some of the issues and problems and “in that actors within the system will be inclined to engage with the changes proposed and the change process itself (B. Williams, 2005, p. 5).”

**Step 7:** Implementing step 6 (YorkU, 2008). For this research, this step requires the participants to take action, thus it will not be covered by the researcher – this research ends in step 6 of SSM. Checkland and Poulter (2010) pointed out: “Some studies will be ended after defining the action, some after implementing it.” (p. 207)
3.5 **RESEARCH DESIGN**

Figure 30: Research Design

Figure 30 is developed based on Checkland (2000, p. 29)’s figure: “The process of SSM” (See appendix C). Figure 30 shows the design of this research that utilises SSM. Bold arrows represent the major stream of data flows while thin arrows show some minor flows and connections between elements. The process of this research is: from the left...
hand side, a literature review is conducted in order to explore the problem situation. Then, a holistic model is built based on the data derived from the literature review. Whilst, on the right hand side of the figure, 5 participants completed and returned the questionnaires, and the data derived from these questionnaires were used to form root definitions, and then 5 conceptual models are constructed. The next phase, as shown in the centre of figure 30, is where the conceptual models (participants perceived reality) are compared and mapped with the holistic model (level 3 model, representing the real world), and then the differences between them are identified. Then solutions are developed with the consideration of three streams analyses of the holistic model, so that the solutions can be systemically desirable (“...in that it will alleviate some of the problems and issues.” (Warwick, 2008, p. 4)) and culturally feasible (“...in that actors within the system will be inclined to engage with the changes proposed and the change process itself.” (Warwick, 2008, p. 4)) to the research object (ICT leasing company in New Zealand). Finally, action is taken to improve the problem situation (a list of recommendations are developed and then the action is taken by the participants).

3.6 DATA COLLECTION PROCESS

3.6.1 Survey questionnaire
A questionnaire (see appendix A) was developed in order to gather data for this research. Having considered the characteristics of SSM, a total of seven questions are developed in the questionnaire that was separated into three parts. In part one, basic demographics information is gathered so that a basic awareness about each participant can be gained, such as the type of their organizations, their positions, levels of understanding to Green ICT issues, and how long they have worked in their organisational positions. Whilst, part two of the questionnaire is designed in the form of the mnemonic – “CATWOE”, which is used in formulating root definitions for SSM, each of the questions represents an element in “CATWOE”. Finally, part three of the questionnaire is designed to gather further data from the participants for the comparison that is conducted between the holistic model (the level 3 model) built from the literature review and participants’ perceptions to Green ICT issues.

This survey was conducted both through online survey using SurveyMonkey and e-mail. Some participants felt that it was more convenient to communicate with the researcher through e-mail and this was preferable to answering an online questionnaire. The online questionnaire was revised based on some participants’ advices in terms of the way questions were expressed so that the participants could have a better understanding of what the questions meant.

3.6.2 Sampling
Purposive sampling is the sampling technique selected for data collection. Zikmund (2003) defines purposive sampling as:
Chapter 3: Methodology

“Judgment, or purposive, sampling is a non-probability sampling technique in which an experienced individual selects the sample based on his or her judgment about some appropriate characteristic required of the sample members” (p. 382)

For this research, due to its qualitative nature, a non-probability sampling technique is required. Five stakeholder groups have been identified (ICT scholar, ICT leasing company in New Zealand, the customer to whom they lease, government body, and New Zealand green group), and the purpose for conducting this survey was to gather data for conceptual model construction (CATWOE and root definitions) in the SSM process. Thus, the researcher chose to select one sample that has the strongest representation as representative from each stakeholder group based on the researcher’s judgment.

3.6.3 Data Analysis Method
The data analysis method for this research follows the process of SSM, (see the Methodology section). Moreover, some analysis works are conducted in the literature review section. It includes the construction of level 1, 2 and 3 models (building a holistic model for the real world), summaries of the models, as well as analysis of the implications.

3.7 Ethical Issues
Ethical issues as defined by John W. Creswell (2009):

“Researchers need to protect their research participants; develop trust with them; promote the integrity of research; guard against misconduct and impropriety that might reflect on their organizations or institutions; and cope with new, challenging problems.” (p. 87)

In collecting data for this research, the processes did not put participants at risks and the vulnerable population were respected by the researcher (Creswell, 2009, p. 89). In addition, an information form was developed (see appendix B) by the researcher to acknowledge that the rights of participants would be protected before the data was collected (Creswell, 2009, p. 89).

In the data analysis phase, names were disassociated from responses. Aliases or pseudonyms have been used for individuals and places in order to protect identities. Once the data analysis phase has been completed, the data will be kept safely for five years.

3.8 Validity of Conceptual Models
Commonly, validity of a model is related to how adequate it can represent the reality (B. Williams, 2005). However since the conceptual models of SSM may not exist, conformance to reality does not appear to be meaningful (B. Williams, 2005). In fact, it is difficult to examine validity of those models generated as part of a SSM and Checkland (1995) suggested that there are aspects that can help to exam the validity of model of
Chapter 3: Methodology

SSM, which are: whether the models as developed are in any sense relevant and whether the models are competently built (Maged & Henshaw, 2009). “Competence” means:

“... ensuring that the root definitions and conceptual models have been derived systematically from the rich picture and the issues identified within it and also that the conceptual models are built only from the root definition. The relevance of the models is a matter for the participants to determine and is related to the extent to which the models generated improve the understanding of issues and the generation of subsequent actions.” (Warwick, 2008, p. 18)

For this research, due to the limitation of further engagement with participants, it was not feasible to go back and discuss these models with the participants. However the researcher so far has gained a deep understanding of the issues regarding the implementation of Green ICT strategies in one ICT leasing company for recycling in New Zealand and the views from these five stakeholders.

3.9 LIMITATION OF SOFT SYSTEMS METHODOLOGY IN THIS RESEARCH

Due to the nature of SSM and the constraints of this research, there are three major limitations that can be identified from this research:

1. Limitation of different worldviews. As shown in figure 26, the worldviews between conventional hard systems thinking and soft systems thinking differ significantly. These differences could create difficulties of understanding for readers who have been trained to be “hard systems” thinkers. Thus these issues have been discussed in this chapter, see the “Soft Systems Thinking” and “Soft Systems Methodology sections.

2. Limitation of further face-to-face engagements with participants. This has been discussed in the last section (Validity of Conceptual Models) that for this research, it was not feasible to conduct further interviews or debates with the five participants. Therefore, the validity of the conceptual models cannot be fully checked. Checkland (2000) outlines, in stage 5 of SSM (see figure 28), comparison of real world and conceptual models, four ways of doing this, which include informal questions, formal questioning (initiating debate), scenario writing based on “operating” the models, and trying to model the real world in the same structure as the conceptual models (p. 43). Of these the second way – formal questioning is the most common way for the comparison to be made (Checkland & Scholes, 2000, p. 43). However, for this research, due to the limitation of conducting further face-to-face engagements with participants, the fourth way – modelling the real world in the same structure (the level 3 holistic models) as the conceptual models for the comparison was chosen.

3. Small sample size. Due to the nature of SSM, this research adopted a qualitative design, which means the results of this research cannot be generalised. This is
appropriate for “soft systems thinkers”. However, as discussed in the first limitation, this could also become a limitation for “hard systems thinkers” to understand.

3.10 CHAPTER SUMMARY
This chapter provides the rationale for the methodology adopted for this research – Soft Systems Methodology, the research questions, the design of the research (see figure 30), sampling technique, data collection, as well as the data analysis methods. Moreover, possible ethical issues that may happen during this research and ways to avoid them are discussed. In addition, the validity of the modelling method in SSM, as well as the limitations of this research are also discussed. In the following chapter, survey result of this research is presented and prepared for conducting data analysis.
Chapter 4: Result of Survey

4 CHAPTER 4: RESULT OF SURVEY

4.1 INTRODUCTION
In order to construct conceptual models for the analysis in the process of Soft Systems Methodology (SSM), a questionnaire (see appendix A) was designed to collect data for “CATWOE” with some basic demographics questions. A survey was conducted online using SurveyMonkey and e-mail. Five stakeholder groups (ICT scholar, ICT leasing company in New Zealand, the customer to whom they lease, government body, and New Zealand Green Party) have been identified and surveyed. In this chapter, the finding from the survey is discussed.

4.2 DATA COLLECTION AND FINDINGS

4.2.1 Part 1 Demographics

Question 1: Which type of organization you work for?

Question 2: What is your position in your organization?

Question 3: How many years you have worked in your field?

Question 4: To what degree do you think you understand “Green ICT” strategies?

This part of the questionnaire is designed for collecting basic demographic information from the five participants. Based on the answers given to these questions, the researcher can determine into which stakeholder group they fall, the level of awareness and understanding about the research topic, as well as their experience in the ICT field. All this information will contribute to the assessment of the quality of the data, thus the researcher can select the most appropriate responses and continue to the data analysis phase.

*Table 8: Summary Table for Part 1 of the Questionnaire*

<table>
<thead>
<tr>
<th>Question</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
<th>Participant 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>Institution</td>
<td>Green group</td>
<td>ICT leasing company</td>
<td>Institution (customer of the ICT leasing company)</td>
<td>Government body</td>
</tr>
<tr>
<td>Question 2</td>
<td>Postgraduate program director (field: ICT pedagogy)</td>
<td>ICT spokesperso n</td>
<td>Service deliver manager</td>
<td>IT manager</td>
<td>Waste minimization project advisor</td>
</tr>
<tr>
<td>Question 3</td>
<td>More than 10 years</td>
<td>Between 1-5 years</td>
<td>Between 1-5 years</td>
<td>Between 1-5 years</td>
<td>Between 1-5 years</td>
</tr>
<tr>
<td>Question 4</td>
<td>Understand quite well</td>
<td>Understand a little</td>
<td>Understand a little</td>
<td>Understand deeply</td>
<td>Understand a lot</td>
</tr>
<tr>
<td>Response</td>
<td>The second</td>
<td>about 3</td>
<td>The second</td>
<td>The second</td>
<td>The second</td>
</tr>
</tbody>
</table>
Chapter 4: Result of Survey

<table>
<thead>
<tr>
<th>Time spent on completing the questionnaire</th>
<th>day</th>
<th>hours</th>
<th>day</th>
<th>day</th>
<th>day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 day</td>
<td>About 3 hours</td>
<td>About 2 months</td>
<td>about 2 weeks</td>
<td>About 3 weeks</td>
</tr>
</tbody>
</table>

| Data collection efficiency               | High | Very high | low | high | low |

| Richness of data*                        | Rich | Slightly rich | Not rich | Very rich | Very rich |

*Richness of data: Judged in terms of the number of words wrote and the issues addressed, see table 10 and 11.

As shown on table 8, participant 1 is a postgraduate program director in an institution in Auckland. He has had 10 years working experience in his position in the field of ICT pedagogy. He claims that he has a good understanding (understand it quite well) about Green ICT strategies. Whilst, while working with this participant, the experience of the researcher indicated that this participant showed a high efficiency in engaging with the questions being asked and a rich set of data was returned to the researcher.

Participant 2 is an ICT spokesperson in a green political party in New Zealand. He has worked for several years (between 1-5 years) in the position and claims he has a little understanding about Green ICT strategy. However, according to the researcher’s experience, this participant has shown very high efficiency in answering the questions for this data collection and has provided the researcher with a slightly rich data through his answer to the questionnaire.

Participant 3 is a manager in an ICT leasing company in New Zealand. He has had several years (between 1-5 years) working experience in his position and claims that he only knows a little about Green ICT strategies. The researcher experienced that this participant showed relatively low efficiency among the rest of the participants and the data collected from him was not rich.

Participant 4 is one of the customers of the ICT leasing company (the company for which Participant 3 works). He is the manager of the IT department in a large institute in Auckland. He has worked in this position for a number of years (between 1-5 years) and thinks he understands issues about Green ICT strategies very well. The researcher found that he has provided very rich data from his answers with a high efficiency of data collection.

Finally, Participant 5 works for a New Zealand government body as a waste minimization project advisor. She has several years working experience in her position (between 1-5 years) and claims she understands a lot about Green ICT strategies. The researcher’s
Chapter 4: Result of Survey

experience shows that she complained about the difficulties in answering the questionnaire due to the complexity of the topic, which indirectly reflects her high level of understanding on the topic. Eventually, she completed the questionnaire and has provided very rich data.

Generally speaking, the researcher has received strong support from all five participants during the data collection phase and most of the participants were positive about this research and showed good insights on this research topic. In terms of response time, all five participants showed different characteristics. The researcher received the quickest response (questionnaire completed) from participant 2 immediately after the contact, and one day after the contact for rest of the participants. In terms of the time spent on completing the questionnaire, participant 2 completed the questionnaire immediately without any further assistance from the researcher; Participant 1 also completed the questionnaire without requesting any further explanation for the questions from the researcher; On the other hand, participants 3, 4 and 5 had difficulties on writing their answers. Participant 3 said in the first contact that he was not capable for answering this questionnaire. Participant 4 did not have a response until the researcher sent him a revised questionnaire, and participant 5 had a discussion with the researcher and gave suggestions about the improvement of the questionnaire. Eventually, participants 3, 4 and 5 had all completed the questionnaire.

4.2.2 Part 2 Green ICT Strategies

Part 2 of the questionnaire (see appendix A) is designed for collecting data for SSM conceptual model construction. There are six questions have been developed, and each one represents one element from “CATWOE” (see the Methodology chapter):

<table>
<thead>
<tr>
<th>Questions</th>
<th>Abbreviation</th>
<th>Elements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>C</td>
<td>“customers”</td>
<td>The victims or beneficiaries of “T”</td>
</tr>
<tr>
<td>Question 2</td>
<td>A</td>
<td>“actors”</td>
<td>Those who world do “T”</td>
</tr>
<tr>
<td>Question 3</td>
<td>T</td>
<td>“transformation process”</td>
<td>The conversion of input to output</td>
</tr>
<tr>
<td>Question 4</td>
<td>W</td>
<td>“weltanschauung”</td>
<td>The worldview which makes this “T” meaningful in context</td>
</tr>
<tr>
<td>Question 5</td>
<td>O</td>
<td>“owner(s)”</td>
<td>Those who could stop “T”</td>
</tr>
<tr>
<td>Question 6</td>
<td>E</td>
<td>“environment, constraints”</td>
<td>Elements outside the system which it takes as given</td>
</tr>
</tbody>
</table>

(Checkland & Scholes, 2000, p. 35)

Question 1 (“C”):

Who would be the benefited or harmed (the impact maybe positive and negative to someone or a group of people) of implementing "Green ICT" strategies in ICT leasing companies for recycling? Anyone you can think of?
Chapter 4: Result of Survey

Answers:

Participant 1 (the scholar): “Society as a whole (and the environment) would benefit. Company profits may be harmed in the short term.”

Participant 2 (the green organization ICT spokesperson): “Everyone will benefit. There may be costs incurred by the consumer, but ultimately someone has to pay for recycling.”

Participant 3 (ICT leasing company service deliver manager): “Public will be benefited.”

Participant 4 (institute IT manager): “Public benefit. Benefits to the Country (reduced cost of landfill strategies; reduced purchasing raw materials; reduced requirement plastics hence petroleum)”

Participant 5 (Waste minimization project advisor from government body): “Beneficiaries - consumers, company, staff, environment, local and national governance bodies. Victims – not sure about using the word 'victim" here. There will be an initial cost to companies to change, and this may translate to additional costs to consumers.”

In summary, all five participants have mentioned that “people” benefit from the implementation of Green ICT strategies in ICT leasing companies, which participant 1 stated as “Society as a whole would benefit”, participant 2 stated “Everyone will benefit.”, participant 3 and 4 stated that the public will benefit, and participant 5 gave a range of stakeholders that would benefit: “…consumers, company, staff, environment, local and national governance bodies.” Moreover, participant 1 mentioned that the environment is also a beneficiary; participant 4 thinks the country can benefit in terms of the economy and use of natural resources. On the other hand, in terms of “Victims” to the implementation of Green ICT strategies in ICT leasing company, three participants gave their opinions except participant 3 and 4. These participants all mentioned that an economic factors, participant 1 and 5 mentioned there will be a cost for the company within the short-term, whilst participant 2 and 5 think there also will be a cost passed on to customers.

Question 2 (“A”):

Who (the actor, someone in the company) do you think would usually implement “Green ICT” strategies in ICT leasing companies for recycling?

Answers:

Participant 1 (the scholar): “The manager or delegated staff member.”

Participant 2 (the green organization ICT spokesperson): “n/a.”

Participant 3 (ICT leasing company service deliver manager): “The manager.”
Participant 4 (institute IT manager): “Strategy Manager (a new role sometimes found nowadays); CIO; CEO.”

Participant 5 (Waste minimization project advisor from government body): “Companies would implement the strategies and staff would carry out the changes.”

For question 2, all participants have given their answers except participant 2 who wrote “n/a”. In summary, participant 1, 3, and 4 mentioned that the manager in the company would usually be the actor who implements Green ICT strategies, which participant 4 specifically identified several roles – “Strategy Manager (a new role sometimes found nowadays); CIO; CEO”. Whilst, participant 1 and 5 mentioned staff’s role in the implementation of Green ICT strategies, which participant 1 thinks that the delegated staff members would also be an actor and participant 5 stated that “Companies would implement the strategies and staff would carry out the changes.”

Question 3 (“T”):

How should ICT leasing companies revise or improve their ICT strategies in order to transform their conventional strategies into "Green" strategies?

Answers:

Participant 1 (the scholar): “They should take proper account of the full life cycle of various products.”

Participant 2 (the green organization ICT spokesperson): “They need to work with ICT manufacturers, customers and legislators to develop life-cycle analysis and responsibility regime so an integrated approach can be developed.”

Participant 3 (ICT leasing company service deliver manager): “????.”

Participant 4 (institute IT manager):
- External audits against a standard
- Cost benchmarking
- Move to virtualization and cloud technology
- Legislation should be introduced requiring (as in some Nordic countries already) that any retail organization selling e.g. TVs be required to accept and dispose in a green way the old TVs received at end of life.”

Participant 5 (Waste minimization project advisor from government body):
“Ideally they would hire a sustainability manager who would ensure the strategies are integrated into business practice rather than being "tack on" strategies with little staff buy in. Alternatively, they could hire a contractor or company that specializes in these sorts of changes, or join an accredited environmental program such as an ISO program, Eco-warranty or Enviro-step.”
Chapter 4: Result of Survey

For question 3, all participants have answered except participant 3 who wrote “????”. In summary, participants 2, 4 and 5 all mentioned the issue of cooperation between different sectors, such as “…work with ICT manufacturers, customers and legislators…” (Participant 2 wrote). Moreover, participant 2 and 5 both mentioned an integrated approach needed to be developed in order to transform the conventional strategies into Green ICT strategies. In the technical aspect, participant 1 and 2 both mentioned that the company needed to focus on life-cycle analysis to their products, and participant 4 has clearly pointed out the use of virtualization and cloud technology. Furthermore, legislation is another factor that has been pointed out by participant 2 and 4, with participant 2 thinks that the company needs to work with legislators to develop life-cycle analysis and responsibility regime, whilst participant 4 thought that legislation for appropriate recycling and disposing e-waste should take place. In addition, participant 4 and 5 pointed out the need for external intervention on the “Green” transformation for ICT strategies, and participant 4 thought that external audits should be taken against the existing standard and implementing cost benchmarking, whilst participant 5 mentioned “Alternatively, they could hire a contractor or company that specializes in these sorts of changes, or join an accredited environmental program such as an ISO program, Eco-warranty or Enviro-step.”

Question 4 (“W”):

How is the implementing of "Green ICT" strategies meaningful to you? Why should we do it? In other words, what are your views on it?

Answers:

Participant 1 (the scholar): “It is important to me because I am concerned about the deteriorating state of the environment and want to leave a better world to my descendants.”

Participant 2 (the green organization ICT spokesperson): “It's important because we face an environmental crisis, as well as natural resource limits. Fast implementers can also benefit through branding opportunities. A Green ICT strategy is essential to a prosperous smart economy.”

Participant 3 (ICT leasing company service deliver manager): “warfare of future generation.”

Participant 4 (institute IT manager):
- Reduces wastage (saves money in the long-term)
- Builds efficiency (reduces requirement for raw materials)
- Builds new niche activities and corporations – hence good for employment
- Contributes (especially in NZ) to a perception of “clean, green” hence good for tourism.”
Participant 5 (Waste minimization project advisor from government body):
“Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating. International pressure and changes are influencing NZ changes in legislation and requirements for business practice. Consumer pressure is also fueling these. Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late.”

For question 4, all participants have given their answers. The environmental factors can be found from participant 1, 2 and 4’s answers. These participants showed concerns on the status of the environment and linkages between implementing Green ICT strategies and the environment. In a broader scope, participant 1, 3 have mentioned a notion of “future generation”, which can be identified as concerns about sustainable issues in a holistic way. Moreover, participant 5 has clearly mentioned the significance of adopting sustainable practices in business, the pressure from international politics, legislation and consumer desire, as well as the advantages a firm will gain through the implementation of Green ICT strategies, such as long-term financial benefits and competitive advantages. Furthermore, participant 2, 4 and 5 also mentioned issues regarding the economy, which participant 2 pointed out that: “A Green ICT strategy is essential to a prosperous smart economy.”; Participant 4 believes that the implementation of Green ICT strategies could “- Reduces wastage (saves money in the long-term), “…good for employment.” and “…good for tourism.” Also, participant 5 has addressed business issues. In addition, two participants (2 and 4) have mentioned the issues regarding the use of natural resources and raw materials.

Question 5 ("O"): Who (individual or groups of people, a name of a role, not name for a specific individual or organization) could stop the implementation of "Green ICT" strategies in ICT leasing companies for recycling?

Answers:

Participant 1 (the scholar): “Shareholders who care only about profits, short-sighted managers and boards.”

Participant 2 (the green organization ICT spokesperson): “Companies need all staff buy-in to move forward. Potentially any unit or member could block it.”

Participant 3 (ICT leasing company service deliver manager): “Government issue.”

Participant 4 (institute IT manager): “Unlikely in NZ. Competitors who produce lower cost items without Green recycling indirectly do this. The answer is legislation.”
Participant 5 (Waste minimization project advisor from government body): “Unless there is strong management "buy in" influencing staff "buy in" to the changes, then attempts to become more sustainable will fail.”

Most of the participants (2, 3, 4 and 5) have mentioned political issues in their answers to this question with participant 2 and 5 pointing out that the implementation of Green ICT strategies in the company requires a systemic movement with the cooperation from staff led by a strong operation of management. Participants 3 and 4 pointed out that the impact from government, because of a lack of legislation could block the implementation of Green ICT strategies. Furthermore, participants 1 and 4 have mentioned economic issues, which also profits from the “un-Greened” products that could be a factor that blocks the implementation of Green ICT strategies. In addition, participant 1’s answer suggested that there were issues regarding the awareness of Green ICT among relevant stakeholders, managers and boards.

Question 6 (“E”):

What are the outside constraints that could hinder or even stop the implementation of "Green ICT" strategies in ICT leasing companies for recycling?

Answers:

Participant 1 (the scholar): “There could be pressure from other companies in the form of competition.”

Participant 2 (the green organization ICT spokesperson):

“Legislation needs to set a framework that encourages beneficial activates like sustainable ICT and not encourage wasteful or inefficient practices. Government can assist with research, funds, levies and regulation.”

Participant 3 (ICT leasing company service deliver manager): “economic.”

Participant 4 (institute IT manager):

“- Economic: if we make it easy for people to sell in a non-Green way e.g. retailers who currently sell batteries. Batteries at end of life are sent to landfill. Very non-Green! Should be legislation requiring retailers to accept old batteries and dispose in a Green way (recycle). Ditto laptops etc.”

Participant 5 (Waste minimization project advisor from government body):

“The current economic recession has decreased many companies interest in becoming more sustainable. Without central government support and policies, it is hard for companies to change as they are voluntarily taking on costs that less sustainable companies do not have. This can make them less competitive in the short term. "Free Riders” - companies that benefit from voluntary changes without participating in funding actions.”
infrastructure or other contributions - are a hindrance to product stewardship schemes and industry wide change.”

Finally, for question 6, all the participants have mentioned economic constraints for the implementation of Green ICT strategies in ICT leasing companies except participant 2. Participant 1 pointed out that there could be pressure from other companies in the form of competition. Participant 3 simply wrote “economic”; participant 4 stated that economic activities should not be carried out in a “non-Green” way; and participant 5 had a diverse discussion about economic impact on the constraints of Green ICT strategies implementation, including the economic recession, business completion, and the “Free Riders”. Moreover, participant 2, 4 and 5 pointed out the possible solutions for overcoming the constraints, which include promotion and legislation for appropriate recycle and disposal activities, government funding and assisting research and development (R&D) on sustainable ICT, and government support for companies that take voluntary changes in sustainable business practices. Furthermore, participant 2 mentioned that sustainable ICT was a solution for these constraints. In addition, participant 4 potentially mentioned that the negative impact of e-waste pollution on the environment.

4.2.3 Summary table for part 2 of the questionnaire

Table 10: Summary Table for Part 2 of the Questionnaire

<table>
<thead>
<tr>
<th>NO.</th>
<th>Elements</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>People will benefit</td>
<td>√ Q1</td>
<td>√ Q1</td>
<td>√ Q1</td>
<td>√ Q1</td>
<td>√ Q1</td>
</tr>
<tr>
<td>2</td>
<td>The environment will benefit</td>
<td>√ Q1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reduce the use of natural resources</td>
<td></td>
<td>√ Q1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cost to the company</td>
<td>√ Q1</td>
<td></td>
<td>√ Q1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cost to customers</td>
<td></td>
<td>√ Q1</td>
<td></td>
<td>√ Q1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Managers are actors</td>
<td>√ Q2</td>
<td>√ Q2</td>
<td>√ Q2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Staff are actors</td>
<td>√ Q2</td>
<td></td>
<td></td>
<td>√ Q2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Need for cooperation between different sectors</td>
<td></td>
<td>√ Q3</td>
<td></td>
<td>√ Q3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Need for an integrated approach</td>
<td></td>
<td>√ Q3</td>
<td></td>
<td></td>
<td>√ Q3</td>
</tr>
<tr>
<td>10</td>
<td>Taking life-cycle analysis to products</td>
<td>√ Q3</td>
<td></td>
<td>√ Q3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>The use of virtualization and cloud technology</td>
<td></td>
<td></td>
<td>√ Q3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Legislation is required and affects the transformation</td>
<td>√ Q3</td>
<td></td>
<td>√ Q3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Need for external intervention to help the transformation</td>
<td>√ Q3</td>
<td></td>
<td></td>
<td>√ Q3</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Meaningful because of it good for the environment</td>
<td>√ Q4</td>
<td>√ Q4</td>
<td></td>
<td>√ Q4</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Meaningful because of it good for the overall sustainable development</td>
<td>√ Q4</td>
<td></td>
<td>√ Q4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Meaningful because of it is good for economy</td>
<td>√ Q4</td>
<td></td>
<td>√ Q4</td>
<td></td>
<td>√ Q4</td>
</tr>
<tr>
<td>17</td>
<td>Meaningful because of it reduce the</td>
<td>√ Q4</td>
<td></td>
<td></td>
<td>√ Q4</td>
<td></td>
</tr>
</tbody>
</table>
### Chapter 4: Result of Survey

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Q5</th>
<th>Q5</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 Requires cooperation from staff</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Lack of legislation could block</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>20 Economic issues could block</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>21 Economic constraints</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>22 Possible solutions to the constraints</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>23 Sustainable ICT is one solution</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>24 Inappropriate disposal of e-waste could cause pollution and it is “non-Green”</td>
<td></td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

Table 10 is a summary table for the answers of part 2 of the questionnaire. All the issues that have been found from the participants’ answers are listed on the left column. Letter “P” showed on the first row of the table is the abbreviation to the word “Participant”, and five participants are numbered from “P1” to “P5”. Moreover, “Q” is the abbreviation for the word “Question”, and this has been numbered to be related to the specific questions in the questionnaire. As shown in the table, participant 4 has addressed the most issues (14 issues) in his answers, participant 2 (12 issues) comes the second place, followed by participant 5 (11 issues) and participant 1 (10 issues). On the other hand, there are only 5 issues has been mentioned by participant 3.

#### 4.2.4 Part 3 External factors

Part 3 of the questionnaire (see appendix A) is designed to gather additional data so that all the data can be integrated and modelled, and then compared and mapped with the level 3 holistic model (figure 21) constructed from literature review.

**Question:**

What impacts do you think the implementation of "Green ICT" strategies could have on: (Please use a few of words, Verb + object, e.g. increase productivity, mitigate climate change?)

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Economy?</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution?</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenhouse gas emission?</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global warming?</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change?</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystem?</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tackling natural disasters?</td>
<td>–</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Answers:

Table 11: Summary Table for Part 3 of the Questionnaire

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economy</strong></td>
<td>Improve efficiency</td>
<td>It would increase productivity and resource use</td>
<td>Increase productivity</td>
<td>Support, diversify</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Pollution</strong></td>
<td>Reduce harmful chemicals in the environment</td>
<td>Reduce pollution</td>
<td>n/a</td>
<td>Reduce, minimize</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Greenhouse gas emission</strong></td>
<td>Reduce CO₂</td>
<td>Reduce</td>
<td>n/a</td>
<td>Potentially reduce</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Global warming</strong></td>
<td>Reduce temperature increases</td>
<td>Reduce</td>
<td>n/a</td>
<td>Possibly reduce</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Climate change</strong></td>
<td>Slow rate of change</td>
<td>Reduce</td>
<td>n/a</td>
<td>Possibly delay</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Ecosystem</strong></td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Impacts can be widespread and specific</td>
</tr>
<tr>
<td><strong>Tackling natural disasters</strong></td>
<td>Reduce frequency and severity</td>
<td>n/a</td>
<td>n/a</td>
<td>See description below</td>
<td>Impacts can be widespread and specific</td>
</tr>
</tbody>
</table>

Participant 4 has given a detailed answer for the last question in part 3:

“Tackling natural disasters? – Possible impact: where landfill requires sealed, lined containers that might be ruptured (earthquake) or destroyed (storms) and hence pollute other adjacent areas.

**Note**: all of these are subject to the methods chosen to recycle. If poor methods mandated, pollution could increase; if ‘good’ methods chose, pollution would decrease”

In summary, most of the answers gathered from the participants indicated that the implementation of Green ICT strategies can bring positive impacts on a range of environmental issues. It can be conjectured that due to the distant relationship between the environmental issues and Green ICT strategies, some questions have not been
answered by the participants. However, for participant 5, she mentioned to the researcher that the impacts of Green ICT strategies implementation are too complex to be described, thus her answer to all the part 3 questions are the same – “Impacts can be widespread and specific”. Furthermore, participant 4 mentioned that inappropriate disposal of e-waste could lead to pollution under natural disasters such as earthquake and storms, and he has further pointed out the recycle methods are the key to solve this type of problems.

4.3 **CHAPTER SUMMARY**

In this chapter, the result of the survey is presented and discussed. In order to construct conceptual models for the analysis in the process of Soft Systems Methodology (SSM), a questionnaire (see appendix A) was designed to collect data for “CATWOE” with some basic demographics questions. A survey was conducted online using SurveyMonkey and e-mail. Five stakeholder groups (ICT leasing company in New Zealand, ICT scholar, the customer to whom they lease, government body, and New Zealand green group) have been identified and surveyed. Based on the result of the survey, summary tables are developed and raw data is made ready to be analysed. Thus in the following chapter, data analysis is conducted following the process of Soft Systems Methodology.
5  CHAPTER 5: DATA ANALYSIS

5.1  INTRODUCTION
In this chapter, the “Three Analyses” of SSM (analysis of the intervention, social systems analysis, and political system analysis) are covered. Moreover, stages 3, 4, 5 and 6 of SSM (see figure 28) are addressed, which are “root definition of relevant purposeful activity systems (stage 3)”, “conceptual models of the systems (holons) named in the root definitions (stage 4)”, and “comparison of models and real world (stage 5)”.

5.2  ANALYSIS OF INTERVENTION (“ANALYSIS ONE” OF SSM)
Having constructed the level 3 holistic model (used as a rich picture here) in the literature review section, the research carries on to the analysis of intervention for the problem situations in the real world (see figure 30 in the Methodology chapter).

There are always three elements involved whenever SSM is used to try and improve a problematical situation – the methodology, the use of the methodology by a practitioner, and the situation (Checkland & Poulter, 2010, p. 211). These are brought together in a particular relationship, in another word, as shown in figure 31, a task is organized by the practitioner to address and intervene using the methodology (Checkland & Poulter, 2010, p. 211). The aim is to take action to improve the problem situation (Checkland & Poulter, 2010, p. 211).

Figure 31: The Three Elements in Any SSM Investigation

Checkland (2010) pointed out there are three key roles always presented in the process that is shown in figure 31:
“1. There was some person (or group of persons) who had caused the intervention to happen, someone without whom, there would not be an investigation at all – this was the role ‘client’.” (p. 211). For instance, the person(s) that could benefit from the investigation.

“2. There was some person (or group of persons) who were conducting the investigation – this was the role ‘practitioner’.” (p. 211).

“3. Most importantly, whoever was in the practitioner role could choose, and list, a number of people who could be regarded as being concerned about or affected by the situation and the outcome of the effort to improve it – this was the role – owner of the issue(s) addressed’.” (p. 211).

Figure 32: SSM’s Analysis One

Figure 32 shows the three elements of “analysis one” of SSM, together with three key roles which always can be identified from the process. From the left hand side of the figure, a “practitioner(s)” carries out the intervention using SSM, then “issue owner(s)” can be chosen and named by this “practitioner(s)” and these “issue owner(s)” can become the source of ideas about relevant worldviews leading to ideas for relevant models.

(Checkland & Poulter, 2006, p. 29)
models. In the “Analysis One” of SSM, after considered the situation displayed in figure 32, there are two questions have to be answered: “Who are in the roles ‘client’ and ‘practitioner’? And who could usefully be included in the list of ‘issue owner’?” (Checkland & Poulter, 2010, p. 212).

For this research, a table has been developed for the analysis of intervention:

**Table 12: Analysis of Intervention**

<table>
<thead>
<tr>
<th>Practitioner</th>
<th>Issue owners</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>The researcher himself</td>
<td>Leasing companies (e-waste recycling) in New Zealand</td>
<td>Public</td>
</tr>
<tr>
<td></td>
<td>The customers of leasing (e-waste recycling) companies in New Zealand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scholars in ICT field</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The New Zealand government</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New Zealand green organizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td></td>
</tr>
</tbody>
</table>

Table 12 shows the list of roles for the research in three groups: practitioner, issue owner and client. Applying the process of SSM “Analysis One” in figure 32, for this research, the researcher himself is the one who carried out the intervention using SSM and a list of the issue owners were chosen. These were: ICT leasing companies in New Zealand; the customers of ICT leasing companies in New Zealand; Scholars in the ICT field; The New Zealand government; New Zealand green organizations; and the public. These identified “issue owners” are sources of the ideas about relevant worldviews leading to ideas for relevant models. In another words, they are sources of data for this research in the stream of the “conceptual world” (see figure 30 in the Methodology chapter, left hand side of the figure). Moreover, the public will benefit from the intervention, thus it is the “client”. For the “role” – public, it is both a “client” and an “issue owner”. Checkland (2010) pointed out: “Thus, the person(s) in the ‘client’ role should be in the list of possible ‘issue owners’ but should very definitely not be the only one in the list.” (p. 213).

Therefore, before the data collection (perceived reality, logical stream) phase of this research, based on the analysis of intervention of SSM, possible stakeholder groups (issue owners, source of data for relevant models) are defined. Then representatives are chosen by the researcher from each of the stakeholder groups and then a survey is conducted using purposive sampling (see the Methodology chapter). However, the role, “public” is a very broad term, which can possibly contain all the roles that have been defined in the analysis of intervention, thus there is no representative that has been chosen by the researcher and this role has not been surveyed.
Furthermore, Checkland (2006) also mentioned the principle of two different ways if using the approach within any SSM-based intervention:

“...one devoted to the perceived content of the problematical situation (SSMc) and one devoted to the intellectual process of the intervention itself (SSMp).” (p. 1)

In this research, since the researcher was using SSM to address the content of the problem rather than the process of dealing with that content, thus this research uses SSM as the way of SSMc.

5.3 SOCIAL SYSTEM ANALYSIS (“ANALYSIS TWO” OF SSM)

It is obvious that when the “practitioner” is going to intervene in, and change a human situation, he or she needs to have a good understanding about what it is intervening in – the “social reality” of the human situation needs to be considered (Checkland & Poulter, 2010, p. 213). In order to develop solutions for the problem situation in which practical actions can be taken, the change involved in the “improvement” needs to be both systemically desirable and culturally feasible, which means: “They need to be possible for these particular people, with their particular history and their particular ways of looking at the world. We have to understand the local ‘culture’, at a level beyond that of individual worldviews.” (Checkland & Poulter, 2010, p. 213).

SSM makes use of a particular model in its “social system” analysis (Checkland & Poulter, 2010, p. 214). The aim is to pin down some sense of the “feel” or “flavour” more firmly, in a way that makes practical sense (Checkland & Poulter, 2010, p. 214).

Figure 33: SSM's Model for Getting a Sense of the Social Texture of a Human Situation

![Diagram of SSM's Model](Checkland & Poulter, 2010, p. 214)

Figure 33 shows the model for obtaining a sense of the social texture of a human situation adopting SSM (Checkland & Poulter, 2010, p. 214). This model may be subtle, the three elements in the model will both endure and change over time (Checkland &
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Poulter, 2010, p. 214). They should be considered in turn, Checkland and Poulter (2010) pointed out: “Roles are social positions which mark differences between members of a group or organization. ...Norms are the expected behaviours associated with, and helping to define, a role. ...Values are the standards – the criteria – by which behaviour-in-role gets judged.” (p. 214)

From the definitions given above, it is not hard to find out that the three elements – roles (formal roles and informal), norms, values – are related to each other closely, dynamically, and they are changing over time as the world goes on (Checkland & Poulter, 2010, p. 214).

Figure 34: "Analysis Two" of SSM

As shown in figure 34, the “Analysis Two” of SSM carries on the work of “Analysis One”, with a consideration in a new aspect added – a dynamic circle of roles, norms, and value, which leads to a question to ask of the real world situation (Checkland & Poulter, 2010, p. 217): what interacting “Roles”, “Norms”, and “Values” characterise this situation? At the end of this analysis, the result yields and contributes to the reflection of the real world situation (Checkland & Poulter, 2010, p. 217).

For this research, the aim for conducting the “Analysis Two” of SSM is to have a clear understanding of the “cultural” circumstances of the real world situation. Then, a meaning of “culturally feasible” for this problematic situation in this research can be defined. This means later when the solutions are being developed for developing and implementing Green ICT strategies in New Zealand, the researcher can look for the solutions with which all the stakeholders can be happy (their feelings, the social aspect of feasibility for the solutions). This is only one aspect of the preparation for developing
“culturally feasible” solutions, the other aspect (political analysis) is addressed in the “Analysis Three” of SSM in the next section.

Table 13: Roles, Norms, and Values for SSM's "Analysis Two"

<table>
<thead>
<tr>
<th>Roles</th>
<th>Norms</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT leasing company</td>
<td>Collecting, recycling e-waste of ICT equipments from customers</td>
<td>Adequately and appropriately dispose and recycle waste ICT equipments without putting the public and the environment at risk.</td>
</tr>
<tr>
<td>The customer of ICT leasing company</td>
<td>Developing organizational Green ICT strategies; Gaining profit; Response to the promotion of Green ICT from government; Abide by the Green ICT regulation.</td>
<td>Have a high level of awareness on Green ICT issues; Green ICT strategies are well developed and dispose ICT e-waste appropriately.</td>
</tr>
<tr>
<td>Scholars in ICT field</td>
<td>Conducting research projects in the field of Green ICT strategies and Green ICTs; Promoting the use of Green ICT and implementation of Green ICT strategies.</td>
<td>Have a high level of awareness on Green ICT issues; Contributing to the knowledge of Green ICT and Green ICT strategies.</td>
</tr>
<tr>
<td>Government</td>
<td>Promoting Research &amp; Development on Green ICT (such as funding and corporation) across governments, higher education, and ICT industry; Developing Green ICT legislations; Promoting Green ICT-related jobs and providing training; Increasing Green ICT application and diffusion; Acting as lead user to Green ICT.</td>
<td>Successfully recover economy and build a sustainable economy through the opportunities which Green ICT provides (e.g. Green ICT is a new economic growth point and help to reduce the use of fossil fuel); Successfully reduce CO₂ emissions through strategies and legislations on ICT; Reduce the pollution caused by e-waste.</td>
</tr>
<tr>
<td>green organizations</td>
<td>Participant in politics and facilitate government’s Green ICT strategies, policies and legislations; Increase Green ICT diffusion; Promoting corporations across firms, industries, and education sector.</td>
<td>Efficiently deliver the will of public (all stakeholders) in terms of Green ICT; Efficiently increase Green ICT diffusion, promoting corporations across firms, industries, and education sector.</td>
</tr>
<tr>
<td>The public</td>
<td>Response to the promotion of Green ICT from government; Abide by the Green ICT regulation; disposal and recycle e-waste of ICT equipments.</td>
<td>Have a high level awareness on the issues of ICT and the environment; Acting in appropriately disposal and recycling ICT waste.</td>
</tr>
</tbody>
</table>

As shown in table 13, “Roles”, “Norms”, and “Values” are listed for the five roles that have been defined in “Analysis One”, which are ICT leasing company, the customer of the ICT leasing company, scholars in the ICT field, government, green organizations, and the public. The information used for conducting this analysis has been found from the literature review (the real world).

5.4 POLITICAL SYSTEM ANALYSIS (“ANALYSIS THREE” OF SSM)

In this section, the analysis of SSM moves to the SSM’s “Analysis Three” – analysis of “political system”. This analysis aims at finding out the power disposition in the situation...
and the processes for containing it (Checkland & Poulter, 2010, p. 217). This is always a significant element in determining the meaning of “culturally feasible”. Politics is another part of culture that has not been addressed directly in the analysis of roles, norms and values in “social system analysis”. There are number of models that have been developed in the “political science” literature for expressing the nature of politics (Checkland & Poulter, 2010, p. 217). However, most of these models are complex. Thus for the “Analysis Three” of SSM, Checkland (2010) pointed out that the analysis follows some basic ideas from the work of Aristotle, which is: “Accommodating different interests is the concern of politics; this entails creating a power-based structure within which potentially destructive power play in pursuit of interests can nevertheless be contained.” (p. 217).

Figure 35: “Analysis Three” of SSM

Figure 35 shows the elements contained in SSM’s “Analysis Three”. Based on the analysis results in “Analysis Two”, political issues in the problematical situation are considered, through asking the question: How is power expressed in this situation (Checkland & Poulter, 2010, p. 217)? Checkland mentioned that to tackle political issues use the metaphor of a “commodity” which embodies power (Checkland & Poulter, 2010, p. 217). He pointed out: “What are the ‘commodities’ which signal that power is possessed in this situation? Then: What are the processes, by which these commodities are obtained, used, protected, defended, passed on, relinquished, etc.?” (Checkland & Poulter, 2010, p. 217).
For this research, all stakeholders have their own characteristics in the situation in terms of politics. Since the development and implementation of Green ICT strategies are highly political, a “political system” analysis needs to be conducted. This will help to find out the “cultural feasibility” of the problem situation when later developing solutions for this situation. Thus, integrating the results from the “Analysis Two”, based on the information provided from the “real world (literature review)”, the “Analysis Three” of SSM is conducted.

ICT leasing companies in this situation are a important actor, that comply with the strategies, policies, and legislations made by government, thus relevant new standards, processes, rules, and techniques need to be developed. There may be initial costs for complying and thus these companies may defend the implementation, because of they need to consider their existing profits. On the other hand, the regulations and promotions in Green ICT, increasing diffusion, and the support for Green ICT education from governments would heighten people’s concern on appropriate ICT e-waste disposal and recycling, thus supporting their business. This should indirectly benefit the ICT leasing companies who also do recycling business, who would welcome Green ICT strategies, policies, and legislations implemented in the power of government.

The customers of ICT leasing companies are broadly distributed across different sectors, mainly firms, organizations, governments, schools and institutions. These roles are affected by the implementation of government’s Green ICT strategies, policies, and legislations, and this may add extra costs on their businesses (e.g. government procurement), thus they may defend the implementation at the beginning. However there is a cost benefit in long-term in the aspect of economy and the environment, gaining a positive reputation from their clients (e.g. customers, public, party and industry association members, and students), thus they may also support the implementation of Green ICT strategies in ICT leasing companies for recycling and the such policies and regulation for governments.

ICT scholars seem to have no direct impact on ICT leasing companies in terms of politics. However, based on the results from the “social systems” analysis, ICT scholars have the power to affect the situation through the knowledge they develop and research they conduct in the field of Green ICT. This provides guidance and insights for governments when they deal with the issues of Green ICT. Moreover, it also helps to increase other stakeholders’ awareness about the Green ICT-related issues, thus adding the political implications between them. For instance, the research results provided by ICT scholars raises attention from green organizations on the issues about ICT and the environment, thus the green organization could make this an agenda for the government and to motivate relevant policy making, or they could conduct propaganda on the issues of ICT and the environment, thus heightening the attention among the public. Generally speaking, ICT scholars are the pioneers in exploring the field of Green ICT, in both
technical and non-technical fields. The impacts generated from them are far-reaching across other sectors.

Governments are the makers of Green ICT policies and legislations that play the most significant role in the situation in terms of politics, which is the central point that the power where all stakeholders have integrated. The impacts and feedback then return to governments through the development and implementation of promotions, corporations, strategies, policies and legislations in terms of Green ICT on a local, national, and international level. Therefore, the delivery of government power (a democratic political structure) on the issues of Green ICT is highly dependent on the desires of other four stakeholders.

Green organizations, such as political parties and other non-political ones (e.g. GeSI), can participate into politics and influence the decisions made by governments, or cooperate with governments and industries for conducting some relevant research. Thus, green organizations’ role in a “politics system” for this particular situation is multi-faceted.

The role – “Public” contains a broad range of stakeholders, which includes all the rest of the stakeholders except “governments”. The will of the public in Green ICT related issues can be reflected by the strategies, policies, and legislations that developed and implemented by governments through ways such as business, Research and Development (R&D), and political movements. Whilst, on the other hand, public is also the object of implementing those strategies, policies, and legislations, as well as the victim if any consequences caused by e-waste and other natural disasters related to ICT (see the level 3 holistic model, figure 8).

5.5 ROOT DEFINITIONS AND CATWOE

Having had the “three analyses” of SSM in the stream of cultural analysis, in this section the logic-based stream of analysis is carried out, which includes forming root definitions and the use of CATWOE mnemonic. Checkland (2010) defines Root Definition (RD) as: “...as statement describing the activity system to be modelled... the metaphor ‘root ’ conveying that this is only one, core way of describing the system.” (p. 219). For CATWOE, Checkland (2010) mentioned:

“When the idea of working with RDs as a source of models was being developed, a further enrichment of the thinking came from having, as a reference, a completely general model of any purposeful activity. (This was a way of declaring exactly what we meant by ‘purposeful activity’. )” (p. 219).

Figure 36 shows the completely general model of any purpose activity and defines CATWOE:

- “Will require people (A) to do the activities which make up T
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- Will affect people (C) outside itself who are its beneficiaries or victims (C for 'Customers')
- Will take as given various constraints from the environment outside itself (E) (such as a body of law, or a finite budget;
- Could be stopped or changed by some person or persons (O) who can be regarded as 'owning' it.” (Checkland & Poulter, 2010, p. 221)

Figure 36: A Generic Model of Any Purposeful Activity, which Yields the Mnemonic CATWOE

(Checkland & Poulter, 2010, p. 221)
Figure 37: Guidelines that Help with Building Models of Purposeful Activities

1. The PQR Formula
   - Do P
   - By Q
   - In order to contribute to achieving R

2. Root Definition

3. Mnemonic
   - CATWOE
   - 'Customers' (victims, beneficiaries)
   - Actors
   - Owners
   - Environmental constraints

4. May be
   - Primary Task
   - Issue-based

5. Leads to
   - Purposeful Activity Model
     - Transformation Process
     - Worldview
     - monitored by criteria for
     - Efficiency (Ei)
     - Effectiveness (Es)

(Checkland & Poulter, 2010, p. 220)

Figure 37 shows the guidelines that help with building models of purposeful activity. Using the PQR formula to form a useful shape for root definition. A PQR formula refers to: do P, by Q, in order to help achieve R, where PQR are used for answering the questions: What? How? and Why (Checkland & Poulter, 2010, p. 219)? Furthermore, CATWOE is also used as enrichment to the root definition. After the root definitions have been built, these may be checked for whether they are “Primary Task” or “Issue-based”
definitions. Finally a purposeful activity model is built based on the root definition (Checkland & Poulter, 2010, p. 222).

For this research, the questionnaire has been designed to collect data from the participants in the form of CATWOE (see the data collection chapter), thus they provide enough relevant data for forming root definitions.

5.5.1 Forming Root Definitions

Participant 1 (the scholar): Improve the conventional ICT strategies in an ICT leasing company to Green ICT strategies by taking proper account of the full life cycle of various products, in order to mitigate the deteriorating state of the environment and leave a better world to descendants.

Participant 2 (the green organization ICT spokesperson): Improve the conventional ICT strategies in an ICT leasing company to Green ICT strategies by working with ICT manufacturers, customers and legislators to develop life-cycle analysis and responsibility regime so an integrated approach can be developed, in order to tackle environmental crisis, mitigate natural resources exhaustion, gaining branding opportunities for firms, as well as supporting a prosperous smart economy.

Participant 3 (ICT leasing company service deliver manager): Improve the conventional ICT strategies in an ICT leasing company to Green ICT strategies in order to support the warfare of future generations (this participant hasn’t given answer to the “T” question, see the data collection section).

Participant 4 (institute IT manager): Improve the conventional ICT strategies in an ICT leasing company to Green ICT strategies by conducting external audits against a standard, setting cost benchmarking, adopting virtualization and cloud technology, as well as introducing legislation, in order to reduce wastage (saves money in the long-term), builds efficiency (reduces requirement for raw materials), builds new niche activities and corporations (hence good for employment), as well as supporting tourism.

Participant 5 (Waste minimization project advisor from government body): Improve the conventional ICT strategies in an ICT leasing company to Green ICT strategies by hiring a sustainability manager who would ensure the strategies are integrated into business practice rather than being "tack on" strategies with little staff buy in, hiring a contractor or company that specializes in these sorts of changes, joining an accredited environmental program such as an ISO program, as well as developing sustainable practices, in order to let businesses being operated continuously, gaining long-term financial benefit, increasing firms’ competiveness, mitigating the pressure outside of the country for sustainability legislation, as well as mitigating pressure from consumer.
5.6 CONSTRUCTING MODELS FOR THE CONCEPTUAL WORLD

Due to the characteristics of this research, one of the limitations that has been discussed in the Methodology chapter is that it is not feasible for the researcher to generate debates later with the participants regarding the problem solutions based on the conceptual models (See the Methodology chapter). Thus the method for data analysis process for this research has been designed as formulating both the data of the real world (level 3 holistic model) and conceptual world (derived from root definitions) into the same form using a general modelling method, so that they can be mapped and compared. Furthermore, for the conceptual models, they are developed based on not only the root definitions but also additional data derived from CATWOE as enrichment.

Figure 38, 39, 40, 41, 42 have been constructed based on the data (root definitions and CATWOE) collected from five participants. In order to be prepared with the real world model, these figures have been formulated in a similar structure to the Level 3 model that has been built. Moreover, the relevant answers (in the form of CATWOE) derived from the questionnaires are presented beside each arrow and marked with the number of the questions so that these data can be prepared for developing a comparison table (Table 14). Furthermore, a mapping for the five conceptual models is conducted and shown as figure 43. At last, a comparison table (table 14) is developed. This summarises the analysis results that were derived from figure 38-42.

As shown in the figure 38, in a macro-perspective, a wide range of issues can be defined directly and indirectly from the answers of this participant. Several loops can be found from the model, for instance the “Politics – Pollution – organization – Politics” loop and the “Organization – ICT – Pollution – organization” loop. This shows that the participant has established a holistic notion for the complexity of ICT related issues. In a micro-perspective, a number of areas have been mentioned by the participant, including ICT, society (organisation), economy, social awareness, politics, and the environment. The model shows that the element “Politics (Green ICT strategies)” is the one which established the most links between other elements. In terms of the element “W” (Q3) and “T” (Q4) of CATWOE, for this participant, the data contribute to the establishment of arrows between: “organization” and “ICT”, external environmental elements and “organizations”, as well as external environmental elements and “politics”.

As shown in figure 39, a conceptual model has been built for the green organization ICT spokesperson. Arrows are established mainly around the central area of the model (layer 2 of the level 1 model – enabled effects), which focuses on the connections between elements “organisations”, “politics”, “social awareness”, “ICT”, and “economy”. The data also covers the area of external factors (see the level 3 model), which links the internal areas (layer 1 and 2 of level 1 model) with those external factors (see level 1 model in the literature review chapter), and then forms a loop that turns back to the internal area (“ecosystems” to “economy”). In terms of the element “W” (Q3) and “T” (Q4) of
CATWOE, for this participant, the data contribute to the establishment of arrows between: “organizations” and “economy”; “ICT” and “economy”, “organizations” and “ICT”, “organizations” and “social awareness”, as well as “politics” to those external environmental elements.

In figure 40, there is only a relatively small area mapped as a conceptual model. This model is constructed based on the data derived from the ICT leasing company’s manager. A lack of information was provided from this participant and especially the data for “T” (Q4) is not covered by him, thus, in terms of the element “W” (Q3) of CATWOE, for this participant, the data contribute to the establishment of arrows between: “organizations” and “sustainability”, and “politics” and “sustainability”.

For figure 41, this conceptual model shows that the institution IT manager’s view, which has some connections between elements are emphasised, such as arrows between “organizations” and “politics”, “organizations” and “economy”, as well as “ICT” and “pollution”. There are also links established from “politics” to external environmental factors, and a loops formed by the link from “ecosystems” to “economy”. In terms of the element “W” (Q3) and “T” (Q4) of CATWOE, for this participant, the data contribute to the establishment of arrows between: “ICT” and “economy”, “ecosystems” and “economy”, “organization” and “economy”, “politics” and “organization”, as well as “politics” and the external environmental factors.

As shown in figure 42, the connections between elements “organization” and “economy”, “organization” and “politics”, “organization” and “sustainability” are strongly covered by this participant (government body representative, waste minimization project advisor). Moreover, connections between “politics” and external environmental factors are also covered. In terms of the element “W” (Q3) and “T” (Q4) of CATWOE, for this participant, the data contributes to the establishment of arrows between: “organizations” and “economy”, “organizations” and “sustainability”, “politics” and “organizations”, “politics” and “sustainability”, as well as “politics” to “economy”.

Figure 43 is an integrated model in which all five conceptual models are mapped and merged as one model. In this model, each participant is marked with a different colour: red for the ICT scholar, green for the green organization ICT spokesperson, blue for the ICT leasing company manager, purple for the institute IT manager, and blown for the government waste minimization project advisor. From this model, the element “Politics” is the one that has the most arrows established (13 arrows), followed by the “Organization” element (8 arrows). All five participants have addressed the issues about “Organizations” and “Politics”, however, the connection between elements “Organization” and “Social Awareness”, “Organization” and “Sustainability”, “Sustainability” and “Economy”, as well as “The environment as a whole” and “Organizations (human)” are rarely address by participants (1 arrow). Furthermore, the element “economy” is the one that has the most arrows pointed at it, and “politics” is
the one from which the most arrows exit. Table 14 is developed in order to provide a further summary for figure 43. The names of five participants (marked in different colour) are put in row against all the elements (based on the holistic level 3 model, see the literature review chapter) which have been defined from participants’ answers from the questionnaire.
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Figure 38: The ICT Scholar's View (Conceptual Model 1)

The ICT scholar's view

Environment as a whole

Ecosystems

Natural disasters

Environment as a whole

Economy

Technology (ICT)

Social Awareness

Politics (Green ICT policies, strategies and legislation)

Pollution

Green house gases emission

Climate change

Global warming

The participant concerned about the deteriorating state of the environment and believes that the implementation of Green ICT strategies could help to leave a better world to his descendants (Q4)

Company profits may be harmed in short term (Q1), some managers and boards are short-sighted and only care about profits (Q5)

Social Awareness

Lack of social awareness of managers and boards (Q5)

Short-sighted and "profits-only" managers and boards would block (Q5)

Reduce frequency and severity (Q7)

Reduce harmful chemicals in the environment (Q7)

Reduce harmful chemicals in the environment (Q7)

Reduce CO2 (Q7)

Reduce temperature increase (Q7)

Slow rate of change (Q7)

Reduce harmful chemicals in the environment (Q7)

The environment as a whole would benefit (Q1), tackling environmental problems and support the sustainability of the environment (Q4)

The environment as a whole would benefit (Q1), tackling environmental problems and support the sustainability of the environment (Q4)

Environment as a whole

The participant concerned about the deteriorating state of the environment and believes that the implementation of Green ICT strategies could help to leave a better world to his descendants (Q4)

Company profits may be harmed in short term (Q1), some managers and boards are short-sighted and only care about profits (Q5)

Social Awareness

Lack of social awareness of managers and boards (Q5)

Short-sighted and "profits-only" managers and boards would block (Q5)

Reduce frequency and severity (Q7)

Reduce harmful chemicals in the environment (Q7)

Reduce harmful chemicals in the environment (Q7)

Reduce CO2 (Q7)

Reduce temperature increase (Q7)

Slow rate of change (Q7)

Reduce harmful chemicals in the environment (Q7)

The environment as a whole would benefit (Q1), tackling environmental problems and support the sustainability of the environment (Q4)

The environment as a whole would benefit (Q1), tackling environmental problems and support the sustainability of the environment (Q4)
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Figure 39: Green Organization ICT spokesperson’s View (Conceptual Model 2)

Organisations

Human

Politics (Green ICT policies, strategies and legislation)

Economy

Technology (ICT)

Social Awareness

We are facing an environmental crisis (Q4)

We are facing an environmental crisis (Q4)

Society would benefit (Q1). Potentially any unit or member could block it. (Q5). Legislation needs to set a framework that encourages beneficial activities like sustainable ICT and not encourage wasteful or inefficient practices. Government can assist with funds, levies and regulation. (Q6)

Fast implementers can also benefit through branding Opportunities (Q4)

Work with legislator to develop a life-cycle analysis and responsibility regime so an integrated approach can be developed (Q3). Companies need all staff buy-in to move forward (Q5)

Ecosystems

We are facing natural resource limits (Q4)

There may be costs incurred by the consumer, but ultimately someone has to pay for recycling(Q1)

Fast implementers can also benefit through branding Opportunities (Q4)

A Green ICT strategy is essential to a preposterous smart Economy (Q4)

It would increase productivity and resource use (Q7)

Reduce (Q7)

Reduce (Q7)

Reduce (Q7)

Reduce (Q7)

Green house gases emission

Climate change

Global warming

Pollution
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Figure 40: The ICT Leasing Company Service Deliver Manager's View (Conceptual Model 3)

The ICT Leasing company manager's view

Economic factors can become the constraints for company for Green ICT strategies implementation (Q6)

Economy

Human
Organisations

The manager is the one implementing Green ICT strategy (Q2)

Public will be benefit (Q1)

Sustainability

Implementing Green ICT strategy contributes to the warfare of future generations (Q4)

Politics (policies, strategies and legislation), Government can affect the implementation of Green ICT strategy

Implementing Green ICT strategy contributes to the warfare of future generations (Q4)
The Institution IT manager's view (Conceptual Model 4)

- **Pollution**
  - Green house gases emission
  - Climate change
  - Possible delay (Q7)
  - Possibly reduce (Q7)
  - Potentially reduce (Q7)

- **Technology (ICT)**
  - Move to virtualization and cloud computing (Q3)
  - Reduce cost of landfill (Q1), Cost benchmarking (Q3), saves money in the long-term (Q4)
  - Economically constrains for the implementation of Green ICT strategies in companies (Q6)
  - Unappropriate way of disposal for batteries are very "non-Green" (Q6), unseal landfill with e-waste would cause pollution if natural disasters come and damage the containers (Q7), poor recycle methods increase the pollution, goods methods decrease the pollution (Q7)
  - Economic factors would be constraint for the implementation of Green ICT strategies (Q6)

- **Human**
  - Reduce, minimize (Q7)
  - Possibly delay (Q7)
  - Reduce, purchasing raw materials and requirement plastics hence petroleum (Q1), good for tourism (Q4)
  - Potentially reduce (Q7)
  - Possibly reduce (Q7)

- **Economy**
  - Build new niche activities and good for employment (Q4)
  - Public, country benefit (Q1), Legislation should be introduced requiring (as in some Nordic countries already) that any retail organization selling eg TVs be required to accept and dispose in a green way the old TVs received at end of life (Q3), builds new niche activities and corporations (Q4), Legislation could block the implementation of Green ICT strategy (Q5), requires legislation to enforce proper way of disposal of e-waste (Q6)
  - Economically constrains for the implementation of Green ICT strategies in companies (Q6)

- **Politics (Green ICT policies, strategies and legislation)**
  - Contributes (especially in NZ) to a perception of "clean, green" (Q4)
  - Contributes (especially in NZ) to a perception of "clean, green" (Q4)

- **Organisations**
  - Reduce purchasing raw materials and requirement plastics hence petroleum (Q1), good for tourism (Q4)

- **Natural disasters**
  - Where landfill requires sealed, lined containers that might be ruptured (earthquake) or destroyed (storms) and hence pollute other adjacent areas. (Q1)
Figure 42: Government Body, Waste Minimization Project Advisor's View (Conceptual Model 5)

A initial cost to companies to change and this may translate to additional costs to consumers (Q1). Not adopting sustainable practices will drive a company out of business eventually; in addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start later (Q4). The current economic recession has decreased many companies interest in becoming more sustainable (Q6).

The environment would benefit from Green ICT strategy implementation (Q1). Impacts can be widespread and specific (Q7). Not adopting sustainable practices will drive a company out of business eventually; in addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start later (Q4). The current economic recession has decreased many companies interest in becoming more sustainable (Q6).

Companies would implement the strategies and staff would carry out the changes (Q2). Hire a sustainability manager who would ensure the strategies are integrated into business practice; hire a contractor or company that specializes in these sorts of changes, or join an accredited environmental program such as an ISO program, Eco-Warranty or Enviro-step (Q3). Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating. International pressure and changes are influencing NZ changes in legislation and requirements for business practice (Q4). Unless there is strong management "buy in" influencing staff "buy in" to the changes, then attempts to become more sustainable will fail (Q5).

The current economic recession has decreased many companies interest in becoming more sustainable (Q6). The environment would be benefit from Green ICT strategy implementation (Q1), impacts can be widespread and specific (Q7). Not adopting sustainable practices will drive a company out of business eventually; in addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start later (Q4). The current economic recession has decreased many companies interest in becoming more sustainable (Q6).
### Chapter 5: Data Analysis

#### Table 14: Comparison Table

<table>
<thead>
<tr>
<th>Politics – The environment (General)</th>
<th>The ICT scholar’s view (CM1)</th>
<th>The green organization ICT spokesperson’s view (CM2)</th>
<th>The ICT leasing company service deliver manager’s view (CM3)</th>
<th>The institution IT manager’s view (CM4)</th>
<th>Government body, waste minimization project advisor’s view (CM5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The environment as a whole would benefit (Q1), 2. Tackling environmental problems and support the sustainability of the environment (Q4)</td>
<td>We are facing an environmental crisis (Q4)</td>
<td>N/A</td>
<td>Contributes (especially in NZ) to a perception of “clean, green”.</td>
<td>The environment would be benefit from green ICT strategy implementation (Q1)</td>
<td></td>
</tr>
<tr>
<td>Politics – Natural disasters</td>
<td>Reduce frequency and severity (Q7)</td>
<td>Reduce (Q7)</td>
<td>N/A</td>
<td></td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Ecosystem</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Contributes (especially in NZ) to a perception of “clean, green”</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Economy</td>
<td>N/A</td>
<td>It would increase productivity and resource use (Q7)</td>
<td>N/A</td>
<td>N/A</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Pollution</td>
<td>Reduce harmful chemicals in the environment (Q7)</td>
<td>Reduce (Q7)</td>
<td>N/A</td>
<td>Reduce, minimize (Q7)</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – GHG emission</td>
<td>Reduce CO2 (Q7)</td>
<td>Reduce (Q7)</td>
<td>N/A</td>
<td>Potentially reduce (Q7)</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Global warming</td>
<td>Reduce temperature increase (Q7)</td>
<td>Reduce (Q7)</td>
<td>N/A</td>
<td>Possibly reduce (Q7)</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Climate change</td>
<td>Slow rate of change (Q7)</td>
<td>Reduce (Q7)</td>
<td>N/A</td>
<td>Possibly delay (Q7)</td>
<td>Impacts can be widespread and specific (Q7)</td>
</tr>
<tr>
<td>Politics – Social awareness</td>
<td>Lack of social awareness of managers and boards (Q5)</td>
<td>Government can assist with research (Q6)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Politics – Organization (Human)</td>
<td>Society as a whole would benefit (Q1), 2. Potentially any unit or member could block it (Q5), 3. Legislation needs to set a framework that encourages beneficial activities like sustainable ICT and not encourage wasteful or inefficient practices. Government can assist with funds, levies and regulation (Q6)</td>
<td>Public will be benefit from the implementation of Green ICT strategy (Q1)</td>
<td>1. Public, country benefit (Q1), Legislation should be introduced requiring (as in some Nordic countries already) that any retail organization selling e.g. TVs be required to accept and dispose in a green way the old TVs received at end of life (Q3), 2. builds new niche activities and corporations (Q4), 3. Legislation could block the</td>
<td>1. Consumers, companies, staff, local and national government bodies would be benefit from Green ICT strategy implementation (Q1), 2. International pressure and changes are influencing NZ changes in legislation and requirements 3. for business practice (Q4)</td>
<td></td>
</tr>
<tr>
<td>Chapter 5: Data Analysis</td>
<td></td>
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<td></td>
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<tr>
<td>-------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Politics – Sustainability</th>
<th>N/A</th>
<th>N/A</th>
<th>Implementing Green ICT strategy contributes to the warfare of future generations (Q4)</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then attempts to become more sustainable will fail (Q5).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. In addition, most sustainable strategies result in long term financial benefits. (Q4)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social awareness – Politics</th>
<th>Short-sighted and “profits-only” managers and boards would block (Q5)</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fast implementers can also benefit through branding Opportunities (Q4)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social awareness – organization</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
</table>

| Organization (Human) – Politics | Implemented by Managers and delegated staff members (Q2) | 1. Work with legislators to develop a life-cycle analysis and responsibility regime so an integrated approach can be developed (Q3), 2. Companies need all staff buy-in to move forward (Q5) | The manager is the one implementing Green ICT strategy (Q2). | 1. The strategy Manager, CIO, CEO would implement Green ICT strategy (Q2), 2. Competitors who produce lower cost items without Green recycling indirectly would block Green ICT strategy implementation (Q5). |
|---------------------------------|-------------------------------------------------|-----------------------------------|-------------------|-----------------------------------|-----------------------------------|
|                                 |                                                | 3. Companies would implement the strategies and staff would carry out the changes (Q2), 2. Hire a sustainability manager who would ensure the strategies are integrated into business practice, hire a contractor or company that specializes in these sorts of changes, or join an accredited environmental program such as an ISO program, Eco-warranty or Enviro-step (Q3), 3. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating. International pressure and changes are influencing NZ changes in legislation and requirements for business practice (Q4), 4. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then |

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Organization (Human) – ICT

<table>
<thead>
<tr>
<th>Text</th>
<th>Result</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full product life cycle analysis for various products (Q3)</td>
<td>N/A</td>
<td>Move to virtualization and cloud computing (Q3)</td>
</tr>
<tr>
<td>Work with ICT manufacturers, customers to develop life-cycle analysis so an integrated approach can be developed (Q3).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Organization – sustainability

<table>
<thead>
<tr>
<th>Text</th>
<th>Result</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Organization and Economy (bi-directional)

<table>
<thead>
<tr>
<th>Text</th>
<th>Result</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company profits may be harmed in short term (Q1).</td>
<td>N/A</td>
<td>1. Ideally companies could hire a sustainability manager who would ensure the strategies are integrated into their business practice (Q3), 2. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating (Q4), 3. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then attempts to become more sustainable will fail (Q5).</td>
</tr>
<tr>
<td>Some managers and boards are short-sighted and only care about profits (Q5).</td>
<td>N/A</td>
<td>1. Ideally companies could hire a sustainability manager who would ensure the strategies are integrated into their business practice (Q3), 2. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating (Q4), 3. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then attempts to become more sustainable will fail (Q5).</td>
</tr>
<tr>
<td>Receiving pressure from other companies in competition (Q6).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>There may be costs incurred by the consumer, but ultimately someone has to pay for recycling (Q1).</td>
<td>(Economy – Organization) Economic factors can become the constraints for company for Green ICT strategies implementation (Q6)</td>
<td>1. Reduce cost of landfill (Q1), 2. Cost benchmarking (Q3), 3. saves money in the long-term (Q4), economic factors are constrains for the implementation of Green ICT strategies in companies 4. Competitors who produce lower cost items without Green recycling indirectly would block Green ICT strategy implementation (Q5).</td>
</tr>
<tr>
<td>Fast implementers can also benefit through branding opportunities (Q4).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>(Economy – Organization) Economic factors can become the constraints for company for Green ICT strategies implementation (Q6)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Reduce cost of landfill (Q1),</td>
<td>N/A</td>
<td>1. Ideally companies could hire a sustainability manager who would ensure the strategies are integrated into their business practice (Q3), 2. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating (Q4), 3. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then attempts to become more sustainable will fail (Q5).</td>
</tr>
<tr>
<td>Cost benchmarking (Q3),</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>saves money in the long-term (Q4), economic factors are constrains for the implementation of Green ICT strategies in companies 4. Competitors who produce lower cost items without Green recycling indirectly would block Green ICT strategy implementation (Q5).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Competitors who produce lower cost items without Green recycling indirectly would block Green ICT strategy implementation (Q5).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sustainability of the business (Q4),</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late (Q4).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late (Q4).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>A initial cost to companies to change and this may translate to additional costs to consumers (Q1), 2. Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late (Q4). 3. Sustainability of the business (Q4), 4. Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late (Q4).</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
changing first will reap these benefits first and gain a competitive advantage over other companies who start late. (Q4)

5. The current economic recession has decreased many companies interest in becoming more sustainable (Q6).

6. Pressure from customers (Q4)

| ICT – Pollution | Reduce harmful chemicals in the environment (Q7) | N/A | N/A | 1. Inappropriate way of disposal for batteries are very “non-Green” (Q6),
2. Unsealed landfill with e-waste would cause pollution if natural disasters come and damage the containers (Q7),
3. Poor recycle methods increase the pollution, goods methods decrease the pollution (Q7) | N/A |
| ICT – Economy | N/A | A Green ICT strategy is essential to a prosperous smart economy (Q4) | N/A | builds new niche activities and good for employment (Q4) | N/A |
| Ecosystems – Economy | N/A | We are facing natural resource limits (Q4) | N/A | 1. Reduce purchasing raw materials and requirement plastics hence petroleum (Q1),
2. Good for tourism (Q4). | N/A |
| Economy – Politics | N/A | N/A | N/A | Economic factors would be constraint for the implementation of Green ICT strategies (Q6) | The current economic recession has decreased many companies interest in becoming more sustainable (Q6). |
| The environment – Organization (Human) | The participant concerned about the deteriorating state of the environment and believes that the implementation of Green ICT strategies could help to leave a better world to his descendants (Q5) | N/A | N/A | N/A | N/A |
| Sustainability – organization (Human) | N/A | N/A | Implementing Green ICT strategy contributes to the warfare of future generations (Q4). | N/A | In addition, most sustainable strategies result in long-term financial benefits. (Q4). |
| Sustainability – Economy | N/A | N/A | N/A | In addition, most sustainable strategies result in long-term financial benefits. (Q4). | N/A |

* "CM" is the abbreviation for phrase “Conceptual Model".
5.7 MAPPING CONCEPTUAL MODELS ONTO THE HOLISTIC LEVEL 3 MODEL

In last section, five conceptual models have been developed in the same form as the holistic level 3 model, which has been developed in the literature review chapter. Checkland (2010) pointed out: “This phase (comparing models with perceived reality) of SSM has usually been referred to as a ‘comparison’ between situation and models...” (p. 226), thus in this section, these five conceptual models are mapped with the holistic level 3 model.

Figure 44, 45, 46, 47 and 48 present the way that these models are mapped onto the level 3 holistic model, and five different colours represent five conceptual models which is further applied to their elements and arrows. The colourful area in figures shows that this area is covered by the conceptual model, whilst the black area in the figure indicates the uncovered area. Furthermore, arrows and elements that have been drawn in thin lines mean that they appear in the conceptual model but have not been addressed by the level 3 holistic model.

As shown in figure 44, CM1 is mapped onto the level 3 holistic model, which is indicated by red colour. Bold lines stand for the parts which CM 1 matches with the level 3 model figure 21). The three thin arrows, CM1-1, CM1-2 and CM1-3 represent new links covered by CM1. They are “Politics – Natural disasters”, “Politics – Ecosystem”, and “The environment as a whole – organization (Human)”. In figure 45, the matching areas are marked as green colour and there are three additional arrows: CM2-1, CM2-2, and CM2-3, which refer to “Politics – Economy”, “Politics – Natural disasters”, and “Politics – Ecosystem”. CM 46 covers a relatively limited area on the L3 model, as shown in figure 47, it is marked using blue colour. However, “Sustainability” is a new element which mentioned by CM3, thus CM3-1 and CM3-2 are new arrows established as “Organizations – Sustainability” and “Politics – Sustainability”. In figure 48, CM4 is marked as purple, new arrows are CM4-1 (Economy – Politics), CM4-2 (Politics – Natural disasters), and CM4-3 (Politics – Ecosystem). In addition, CM5 is marked as brown colour in figure 49. There are five new arrows are mentioned, which are CM5-1 (Sustainability – Economy, and a bi-directional link: Organization- Sustainability), CM5-2 (Politics – Sustainability), CM5-3 (Politics – Economy), CM5-4 (Politics – Natural disasters), and CM5-5 (Politics – Ecosystem).

Table 15 is a summary table developed for mapping the real world situation onto the conceptual world. It takes the results of table 4 and 5, and then mapped onto table 14. Moreover, it also provided additional illustrations for figure 44, 45, 46, 47 and 48. Table 15 has three parts, which are “ICT’s direct impact (layer 1)”, “ICT’s enabled impact (layer 2)”, and “systemic effects (layer 3)”. These three parts refer to the three layers that have been developed in the level 1 model in the literature review chapter. Furthermore, on the left hand side, arrow numbers and involved elements are listed, followed by a list of the major impacts identified from the level 3 model for those arrows. A double-line is
placed to separate the columns of the real world and the conceptual world (on the right). The answers of the five participants are rearranged and mapped following the order of the level 3 model. As shown in Table 15, taking a macroscopic view, layer 2 (enabled impact of ICT) is the layer that is well addressed by the five conceptual models, the rest of layers (direct impact and systemic effects) are relatively rarely addressed. On the other hand, there are also issues that have not been covered by the Level 3 model (represent the real world situation), which are arrows whose names start with “CM”.

5.8 **CHAPTER SUMMARY**
In this chapter, data collected is analysed following the process of SSM. The “Three Analyses” of SSM (analysis of the intervention, “social systems” analysis, and “political system” analysis) are covered. Moreover, stages 3, 4, 5 and 6 of SSM are addressed (see Figure 27 and section 5.5 – 5.7), which are “root definition of relevant purposeful activity systems (stage 3)”, “conceptual models of the systems (holons) named in the root definitions (stage 4)”, and “comparison of models and real world (stage 5)”. Five conceptual models are built based on the data collected from the five participants, and then these are mapped with the level 3 holistic model respectively, which has been constructed from reviewing relevant literature. At the end of this chapter, a summary table is designed for the mapping results. In next chapter, this research is concluded and recommendations for developing and implementing Green ICT strategies for recycling in New Zealand is proposed, along with a model for specific solution development for the stakeholders.
Figure 44: Mapping CM 1 onto the Level 3 Holistic Model

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Figure 45: Mapping CM 2 onto the Level 3 Holistic Model

1. Contribute to (Energy consumption and on the other hand help to reduce)
2. Negative impact
3. ICT Support and accelerate economy
4. a. People with skills and awareness in Green ICT support its development
5. Support
6. Market driven
7. Create and use
8. Contribution to economy
9. Better handled by remote sensing technology and GIS
10. Support
11. Tackling
12. Tackling
13. Negative impact
14. New shipping routes
15. Absorb infrared light
16. Antarctic ice melting, extra green houses gases release from the soil.
17. Lead to
18. Global warming
19. Negative impact
20. Negative impact
21. Negative impact
22. Ecosystem degradation creates disaster risks
23. Negative impact
24. Natural disasters
25. 26. Social Awareness
26. Social awareness guide human’s behaviours
27. Affect policies and strategies making
28. Social responsibilities guide human’s behaviours
29. CM2-2
CM2-1
CM2-3
30. Politics (policies, strategies and legislation)
31. CM2-4
32. Industry participant in the implementation of Green ICT policies and strategies
33. ICT support communication increase social awareness, education
34. Support
35. Technology (ICT)
36. Support
37. Taking, and providing resources
38. Ecosystem
39. Human
40. Organisations
41. Ecosystem
42. 43. Climate change
44. Pollution
45. Green house gases emission
46. Negative impact
47. Negative impact
**Chapter 5: Data Analysis**

**Figure 46: Mapping CM 3 onto the Level 3 Holistic Model**

Ecosystem degradation creates disaster risks, leading to negative impacts on the ecosystem, economy, and technology (ICT). Negative impacts include pollution and climate change. Ecosystem degradation affects social awareness, leading to increased social awareness and education. People with skills and awareness in Green ICT support its development, leading to increased support and accelerated economy. ICT applications contribute to energy consumption and the other hand help to reduce GHG emissions through smart ICT applications. E-waste, ICT applications contribute to energy consumption and the other hand help to reduce GHG emissions through smart ICT applications. New shipping routes lead to global warming and negative impacts. Opportunities and challenges are handled by remote sensing technology and GIS. Organisations support the implementation of Green ICT strategies for organizations. Social responsibilities guide human behaviors, leading to tackling environmental problems through implementing Green ICT policies and strategies. Politics (policies, strategies and legislation) and human responsibilities affect policies and strategies making and raising awareness and providing education. Tackling environmental problems through implementing Green ICT policies and strategies contribute to energy consumption and the other hand help to reduce. CM3-1 and CM3-2 guide sustainability.
Chapter 5: Data Analysis

Figure 47: Mapping CM 4 onto the Level 3 Holistic Model

1. Contribute to energy consumption and on the other hand help to reduce
2. People with skills and awareness in Green ICT help its development
3. ICT support and stimulating smart ICT applications
4. ICT support communication, increase social awareness, education
5. Market driven
6. Create and use
7. Social responsibilities guide human’s behaviours
8. Opportunities
9. Better handled by remote sensing technology and GIS
10. Support and accelerating economy
11. New shipping routes
12. Tackling
13. Negative impact
14. Negative impact
15. Absorb infrared light
16. Antarctic ice melting, extra greenhouse gases release from the soil.
17. Lead to Global warming
18. Lead to New shipping routes
19. Lead to
20. Negative impact
21. Negative impact
22. Ecosystem degradation creates disaster risks
23. Taking, and providing resources
24. Natural disasters
25. Politics (policies, strategies and legislation)
26. Raising awareness and providing education
27. Affect policies and strategies making
28. Social Awareness
29. Stimulating, promoting green ICT, and developing Green ICT strategies for organizations
30. Industry participant in the implementation of Green ICT policies and strategies

CM4-1

CM4-2

CM4-3
Chapter 5: Data Analysis

Figure 48: Mapping CM 5 onto the Level 3 Holistic Model

1. Contribute to energy consumption and on the other hand help to reduce
   - Reduce GHG emission through smart ICT applications
   - E-waste, ICT applications

2. People with skills and awareness in Green ICT support its development
   - New shipping routes
   - E-waste, ICT applications

3. Negative impact
   - Negative impact

4. ICT support and accelerate economy
   - Market driven

5. Technology (ICT)
   - Create and use
   - Social responsibilities guide human’s behaviour

6. Organizations
   - Human

7. ICT support communication and raise social awareness and education

8. Opportunities

9. Better handled by remote sensing technology and GIS

10. Negative impact
   - Support

11. Tackling environmental problems through implementing Green ICT policies strategies

12. Tackling

13. Lead to
   - Taking, and providing resources

14. Climate change
   - Lead to

15. Global warming
   - Antarctic ice melting, extra green houses gases release from the soil.

16. Absorb infrared light

17. Negative impact
   - Negative impact

18. Green house gases emission
   - New shipping routes

19. Ecosystem degradation creates disaster risks

20. Negative impact

21. Lead to

22. Negative impact
   - Support

23. Taking, and providing resources

24. Natural disasters

25. Politics (policies, strategies and legislation)
   - Tackling environmental problems through implementing Green ICT policies strategies

26. Social Awareness
   - Raising awareness and providing education

27. Affect policies and strategies making

28. Industry participant in the implementation of Green ICT policies and strategies

29. Stimulating, promoting green ICT, and developing Green ICT strategies for organizations

30. Social Awareness
   - Raising awareness and providing education

31. Tackling environmental problems through implementing Green ICT policies strategies

32. People with skills and awareness in Green ICT support its development

33. Negative impact

34. Negative impact
**Table 15: Summary Table for Mapping Results**

<table>
<thead>
<tr>
<th>Arrow Number</th>
<th>Elements involved</th>
<th>Real World (L3 Model)</th>
<th>Conceptual World – implementing Green ICT strategies in ICT leasing companies (CATWOE + Q7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICT-Pollution</td>
<td>E-waste causes pollution (Huisman et al., 2007; The applications of Green ICT tackle pollution (Weber, 2009, p. 47).</td>
<td>The ICT scholar’s view (CM1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce harmful chemicals in the environment (Q7).</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>ICT-GHG emission</td>
<td>Contribute to GHG emission (T-systems, 2010); Green ICT helps reduce GHG emission produced by ICT sector (T-systems, 2010).</td>
<td>N/A</td>
</tr>
<tr>
<td>4a</td>
<td>ICT-social awareness;</td>
<td>ICT enhance communication so that support to increase social awareness (Hasan et al., 2009; Hasan &amp; Kazlauskas, 2009b); Necessity in educating Green ICT (Organization for Economic Cooperation and Development, 2009a)</td>
<td>N/A</td>
</tr>
<tr>
<td>5a</td>
<td>ICT-economic</td>
<td>ICT is about to play an increasingly significant role as a critical enabler of sustainable and renewed growth of economy (Dutta &amp; Mia, 2010)</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>ICT-organization</td>
<td>Green ICT solutions can support business process by streamlining processes and potentially helping companies to reduce CO2 emission by improving the utilization of resources and allowing them to be shared (T-systems, 2010).</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Chapter 5: Data Analysis

| ICT-natural disasters | ICTs have been fully applied across climate-related disaster management (Yap, 2011). | N/A | N/A | N/A | N/A | N/A |
| ICT-ecosystem | ICTs have been widely applied throughout the area of environmental observation, analysis, planning, and management (International Telecommunication Union, 2008a, p. 25). | N/A | N/A | N/A | N/A | N/A |
| ICT-global warming | ICTs have been widely applied throughout the area of environmental observation, analysis, planning, and management (International Telecommunication Union, 2008a, p. 25). | N/A | N/A | N/A | N/A | N/A |
| ICT-climate change | ICTs have been widely applied throughout the area of environmental observation, analysis, planning, and management (International Telecommunication Union, 2008a, p. 25). | N/A | N/A | N/A | N/A | N/A |

**ICT’s enabled impact (layer 2)*

<table>
<thead>
<tr>
<th>Real World (L3 Model)</th>
<th>Conceptual World – implementing green ICT strategies in ICT leasing companies (CATWOE + Q7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow Number</td>
<td>Elements involved</td>
</tr>
<tr>
<td></td>
<td>Major impact (in the Level 3 holistic model)</td>
</tr>
<tr>
<td></td>
<td>The ICT scholar’s view (CM1)</td>
</tr>
<tr>
<td></td>
<td>The green organization ICT spokesperson’s view (CM2)</td>
</tr>
<tr>
<td></td>
<td>The E-waste leasing company service deliver manager’s view (CM3)</td>
</tr>
<tr>
<td></td>
<td>The institution IT manager’s view (CM4)</td>
</tr>
<tr>
<td></td>
<td>Government body, waste minimization project advisor’s view (CM5)</td>
</tr>
<tr>
<td>3</td>
<td>Economy-GHG emission</td>
</tr>
<tr>
<td></td>
<td>Reduce GHG emission through smart ICT applications and dematerialization (The Climate Group &amp; Global e-Sustainability Initiative, 2008).</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>Organization and economy (bi-directional)</td>
</tr>
<tr>
<td></td>
<td>Green ICT in a new growth point of economy and provide organization opportunities (Mickoleit et al., 2009).</td>
</tr>
<tr>
<td></td>
<td>1. Company profits may be harmed in short term (Q1”C”); 2. Some managers and boards are short-sighted and only care about profits (Q5”O”); 3. Receiving pressure from other companies in competition (Q6”E”).</td>
</tr>
<tr>
<td></td>
<td>3. There may be costs incurred by the consumer, but ultimately someone has to pay for recycling (Q1”C”); 4. Fast implementers can also benefit through branding opportunities (Q4”W”).</td>
</tr>
<tr>
<td></td>
<td>(Economy – Organization) Economic factors can become the constraints for company for Green ICT strategies implementation (Q6”E”).</td>
</tr>
<tr>
<td></td>
<td>5. Reduce cost of landfill (Q1); 6. Cost benchmarking (Q3”T”); 7. Saves money in the long-term (Q4”W”), economic factors are constrains for the implementation of Green ICT strategies in companies. 8. Competitors who produce</td>
</tr>
<tr>
<td></td>
<td>7. A initial cost to companies to change and this may translate to additional costs to consumers (Q1”C”); 8. Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long-term financial benefits. Those who start changing first will reap</td>
</tr>
</tbody>
</table>
Chapter 5: Data Analysis

<table>
<thead>
<tr>
<th>No.</th>
<th>E-waste pollution – human health</th>
<th>These toxic substances could result in a range of human health problems (Swedish Environmental Protection Agency, 2011).</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>14</td>
<td>Pollution – global warming</td>
<td>Aerosol particles work as a “mask”, blocks the full effect of Greenhouse gases radiative forcing to heat the Earth (United Nations Environment Programme, 2009a, p. 10).</td>
</tr>
<tr>
<td>15</td>
<td>GHG emission - global warming</td>
<td>Large amount of GHGs trap the infrared radiation from sunlight, so that cause Greenhouse effect (United Nations Environment Programme &amp; GRID-Arendal, 2002).</td>
</tr>
<tr>
<td>16</td>
<td>Global warming- GHG emission</td>
<td>Extra CO₂ and methane can release from the Arctic freezing soils (United Nations Environment Programme, 2009a, p. 19).</td>
</tr>
</tbody>
</table>

lower cost items without Green recycling indirectly would block Green ICT strategy implementation (Q5"O").

these benefits first and gain a competitive advantage over other companies who start late (Q4"W").

9. Sustainability of the business (Q4"W");
10. Not adopting sustainable practices will drive a company out of business eventually. In addition, most sustainable strategies result in long-term financial benefits. Those who start changing first will reap these benefits first and gain a competitive advantage over other companies who start late. (Q4"W");
11. The current economic recession has decreased many companies interest in becoming more sustainable (Q6"E");
12. Pressure from customers (Q4"W").
| 17 | Global warming-climate change | A warming planet leads to climate to change in a way of affect weather in various ways, such as the increase rate of extreme weather events, ocean current change, and monsoon disruptions (Shah, 2011; J. B. Smith et al., 2009; United Nations Environment Programme, 2009a). | N/A | N/A | N/A | N/A | N/A |
| 18 | Global warming-economy | Due to the rise of sea level and melting of sea ice caused by global warming, particularly in Arctic, lead to the accessibility of new shipping routes and exploitation of natural resources (World Trade Organization & United Nations Environment Programme, 2009, p. 12). | N/A | N/A | N/A | N/A | N/A |
| 19 | Climate change-natural disaster | Global climate change can lead to serious consequences such as frequent and intense natural disasters such as floods, droughts, storms, heavy precipitation, as well as ecosystem degradation (United Nations Environment Programme, 2009b). | N/A | N/A | N/A | N/A | N/A |
| 20 | Climate change-ecosystem | Climate change creates significant risks on ecosystem, causing irreversible loss of unique and threatened systems, include endangered species, coral reefs, biodiversity hotspots, unique ecosystems, unique ecosystems and indigenous communities (J. B. Smith et al., 2009). | N/A | N/A | N/A | N/A | N/A |
| 21 | E-waste pollution-ecosystem | Toxic to ecosystem, up taken by biota, and contaminate air, water and soil (Sepúlveda et al., 2010). | N/A | N/A | N/A | N/A | N/A |
| 22 | Ecosystems – human | Ecosystems with biodiversity are essential to mankind by providing a range of services. (Shaikh, 2010; United Nations Environment Programme, 2010a). They also provide sinks for our waste and are source of life-saving drugs (European Communities, 2008c). | N/A | N/A | N/A | N/A | N/A |
| 23 | Ecosystem and economy (bi-directional) | Ecosystem can protect economy investment by providing goods and services which contain | N/A | We are facing natural resource limits (Q4“W”). | N/A | 3. Reduce purchasing raw materials and requirement | N/A |
| 24  | Ecosystem – natural disasters | The function of healthy ecosystems (such as forests, wetlands and coastal areas) is to provide buffers to extreme events, especially for people whose lives are rely on natural resources and physical security (International Union for Conservation of Nature, 2010). | N/A | N/A | N/A | N/A | N/A |
| 25  | Green ICT policies and strategies – environmental problems | Tackling environmental problems through implementing Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009). 1. The environment as a whole would benefit (Q1”C”); 2. Tackling environmental problems and support the sustainability of the environment (Q4”W”). We are facing an environmental crisis (Q4”W”). | N/A | N/A | N/A | N/A | N/A |
| 26  | Social awareness – environmental problems | Increase social awareness through policies and strategies in terms of Green ICT. Tackling environmental problems through implementing Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009). Reduce harmful chemicals in the environment; Reduce CO2; Reduce temperature increase; slow rate of change (Q7). | Reduce (Q7). | N/A | Minimize pollution; Potentially reduce GHG emission; Possibly reduce global warming; Possibly delay climate change. (Q7). | Impacts can be widespread and specific (Q7). |
| 27 a&b | Green ICT policies & strategies and social awareness (bi-directional) | Educating users and customers about ICT and the environment; Training expertise in Green ICT area and response to the large demand of people with such skills (Organization for Economic Co-operation and Development, 2009). Lack of social awareness of managers and boards; Short-sighted and “profits-only” managers and boards would block the implementation (Q5”O”); Government can assist with research (Q6”E”). | N/A | N/A | N/A | N/A |
| 28  | Organization and social awareness (bi-directional) | Industry associations and business have started working on the increase of social awareness among their members and employees (Organization for Economic Co-operation and Development, 2009). Implemented by managers and delegated staff members (Q2”A”). Fast implementers can also benefit through branding Opportunities (Q4”W”). | N/A | N/A | N/A | N/A |
| 29a | Organization to Green ICT policies & strategies | Stimulating, promoting Green ICT, and developing Green ICT strategies for organizations; Industry participant in the implementation of Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009). Implemented by managers and delegated staff members (Q2”A”). 1. Work with legislators to develop a life-cycle analysis and responsibility regime so an integrated approach can be developed (Q3”T”); The manager is the one implementing Green ICT strategy (Q2”A”). 1. The strategy Manager, CIO, CEO would implement Green ICT strategy (Q2”A”); 2. Competitors who produce lower cost items without competition (Q4”W”). | N/A | N/A | N/A | N/A |
2. Companies need all staff buy-in to move forward (Q5“O”).

Green recycling indirectly would block Green ICT strategy implementation (Q5“O”).

3. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating. International pressure and changes are influencing NZ changes in legislation and requirements for business practice (Q4“W”);

4. Unless there is strong management “buy in” influencing staff “buy in” to the changes, then attempts to become more sustainable will fail (Q5“W”).

29b Green ICT policies & strategies to organization

Stimulating, promoting green ICT, and developing Green ICT strategies for organizations; Industry participant in the implementation of Green ICT policies and strategies (Organization for Economic Co-operation and Development, 2009e).

Society as a whole would benefit (Q1“A”).

1. Society would benefit (Q1“C”);
2. Potentially any unit or member could block it (Q5“O”);
3. Legislation needs to set a framework that encourages beneficial activities like sustainable ICT and not encourage wasteful or inefficient practices. Government can assist with funds, levies and regulation (Q6“E”).

Public will be benefit from the implementation of Green ICT strategy (Q1“A”)  

1. Public, country benefit (Q1“A”). Legislation should be introduced requiring (as in some Nordic countries already) that any retail organization selling e.g. TVs be required to accept and dispose in a green way the old TVs received at end of life (Q3“A”);
2. builds new niche activities and corporations (Q4“W”);
3. Legislation could block the implementation of Green ICT strategy (Q5“O”);
4. Requires legislation to enforce proper way of disposal of e-waste

1. Consumers, companies, staff, local and national government bodies would be benefit from Green ICT strategy implementation (Q1“C”);
2. International pressure and changes are influencing NZ changes in legislation and requirements
3. For business practice (Q4“W”).
| CM1-2 | Green ICT policies & strategies – Natural disasters | N/A | Reduce frequency and severity (Q7) | Reduce (Q7) | N/A | Where landfill requires sealed, lined containers that might be ruptured (earthquake) or destroyed (storms) and hence pollute other adjacent areas. (Q1“C”). | Impacts can be widespread and specific (Q7). |
| CM1-3 | Green ICT policies & strategies – Ecosystems | N/A | N/A | N/A | N/A | Contributes (especially in NZ) to a perception of “clean, green” (Q4“W”). | Impacts can be widespread and specific (Q7). |
| CM1-1 | The environment as a whole – organization (Human) | N/A | The participant concerned about the deteriorating state of the environment and believes that the implementation of Green ICT strategies could help to leave a better world to his descendants (Q4“W”). | N/A | N/A | N/A | N/A |
| CM2-1 | Green ICT policies & strategies – Economy | N/A | N/A | N/A | N/A | Economic factors would be constraint for the implementation of Green ICT strategies (Q6“E”). | The current economic recession has decreased many companies interest in becoming more sustainable (Q6“E”). |
| CM3-2 | Green ICT policies & strategies – Sustainability | N/A | N/A | N/A | Implementing Green ICT strategy contributes to the warfare of future generations (Q4“W”). | N/A | 1. Unless there is strong management "buy in" influencing staff "buy in" to the changes, then attempts to become more sustainable will fail (Q5“O”); 2. In addition, most sustainable strategies result in long-term financial benefits (Q4“W”). |
| CM3-1 | Organization and Sustainability (bidirectional) | N/A | N/A | N/A | Implementing Green ICT strategy contributes to the warfare of future generations (Q4“W”). | N/A | 1. Ideally companies could hire a sustainability manager who would ensure the strategies are integrated into their business practice (Q3“T”); 2. Companies need to develop sustainable practices as a fundamental part of their business practices in order to be able to continue operating (Q4“W”). |
Chapter 5: Data Analysis

3. Unless there is strong management "buy in" influencing staff "buy in" to the changes, then attempts to become more sustainable will fail (Q5"O").
4. In addition, most sustainable strategies result in long-term financial benefits (Q4"W").

| CM5-1 | Sustainability – economy | N/A | N/A | N/A | N/A | N/A | In addition, most sustainable strategies result in long-term financial benefits (Q4"W"). |
| CM4-1 | Economy and Green ICT policies & strategies | N/A | N/A | N/A | N/A | N/A | Economic factors would be constraint for the implementation of Green ICT strategies (Q6"E"). The current economic recession has decreased many companies interest in becoming more sustainable (Q6"E"). |

**Systemic effects (layer 3)**

<table>
<thead>
<tr>
<th>Real World (L3 Model)</th>
<th>Conceptual World – developing and implementing Green ICT strategies in ICT leasing companies (CATWOE + Q7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow Number</td>
<td>Elements involved</td>
</tr>
<tr>
<td>5b</td>
<td>Economy – ICT</td>
</tr>
<tr>
<td>4b</td>
<td>Social awareness – ICT</td>
</tr>
<tr>
<td>7</td>
<td>Organisations – ICT</td>
</tr>
</tbody>
</table>

* See the level 1 model in the literature review chapter for the discussion of different layers.
6 CHAPTER 6: CONCLUSION

6.1 SOLUTIONS AND RECOMMENDATIONS

Having had the real world model and conceptual models mapped and compared, and the “Three Analyses” conducted, in this chapter, the final stage (stage 6 of SSM, see figure 28) of SSM is addressed. In this stage, a list of recommendations that contribute to the development of systemically desirable and culturally feasible solutions for the situation is proposed.

For the development of solutions in SSM, Checkland (2010) pointed out that:

“... the aim is the same: to find a version of the real situation and ways to improve it which different people with different worldviews can nevertheless live with. Outside of the arbitrary exercise of power, this is the necessary condition which must be met in any human group if agreed ‘action to improve’ is to be defined.” (p. 229)

“It (SSM) works with the idea of finding an accommodation among a group of people with a common concern.” (p. 229)

Therefore, for this research, in terms of seeking accommodation among this group of people (five representatives whose positions are high in their respective organizations) who have different worldviews (the “W”), and potential solutions (the “T”) to this situation, and to have a common concern (concern of implementing green ICT strategies), thus solutions should be developed with a consideration that these people could probably all feel acceptable. Moreover, based on the result of the “Three Analyses” of SSM and the model mapping, a solution could also be developed to be “systemically desirable” and “culturally feasible”, which means these solutions derived from the “relevant systems” need to be in fact perceived to be truly relevant and will alleviate some of the problems, and also the actors within the system will be inclined to engage with the changes proposed and the change process itself (Checkland & Scholes, 2000, p. 52; Warwick, 2008).

Figure 49: Model for Solution Development

*CF: Culturally Feasible; SD: Systemically Desirable; 3 “Es”: Effectiveness, efficiency and efficacy.
Due to one of the limitations of this research, the analysis of this stage of SSM cannot be generated from debates and discussions with participants, thus recommendations for developing general solutions are developed rather than specific ones. Figure 49 indicates the model of how the solutions for this research are developed. “Ts” mean the “Transformation processes” form participants’ views that are a source of possible solutions. Then the “Transformation processes” are accessed and analysed based on the results of the “Three Analyses” of SSM, “W” (Worldviews of participants), and the result of model mapping (L3 and CMs) in terms of “systemically desirable” (SD) and “culturally feasible” (CF). At last, final solutions are derived and developed from this analysis.

Table 16: Part of Table 10

<table>
<thead>
<tr>
<th>NO.</th>
<th>Elements</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Need for cooperation between different sectors</td>
<td>√ Q3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Need for an integrated approach</td>
<td></td>
<td>√ Q3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Taking life-cycle analysis to products</td>
<td></td>
<td>√ Q3</td>
<td>√ Q3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>The use of virtualization and cloud technology</td>
<td></td>
<td></td>
<td></td>
<td>√ Q3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Legislation is required and affects the transformation</td>
<td></td>
<td></td>
<td></td>
<td>√ Q3</td>
<td>√ Q3</td>
</tr>
<tr>
<td>13</td>
<td>Need for external intervention to help the transformation</td>
<td></td>
<td></td>
<td>√ Q3</td>
<td>√ Q3</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Meaningful because of it good for the environment</td>
<td></td>
<td>√ Q4</td>
<td>√ Q4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Meaningful because of it good for the overall sustainable development</td>
<td>√ Q4</td>
<td></td>
<td></td>
<td>√ Q4</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Meaningful because of it good for economy</td>
<td></td>
<td>√ Q4</td>
<td>√ Q4</td>
<td>√ Q4</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Meaningful because of it reduce the requirement of natural resources</td>
<td></td>
<td>√ Q4</td>
<td></td>
<td></td>
<td>√ Q4</td>
</tr>
</tbody>
</table>

Table 16 shows the issues that have been addressed by “T” (Q3) from the participants. There are possible solutions in these five areas: cooperation, approach integration, life-cycle analysis, new technology adoption, legislation and external intervention.

In the data analysis chapter, all participants’ answers for “T” and “W” have been presented in table 10. Thus, when companies develop and implement their Green ICT strategies for ICT recycling, it is recommended they consider following issues:

1. Establish co-operation with other sectors or getting support from other external organizations.
2. Develop an integrated approach through cooperation or external support.
3. Green ICTs such as virtualization and cloud technologies can be adopted.
4. Legislation is a factor that could affect the development and implementation of Green ICT strategies.
5. The practitioners who are responsible for Green ICT strategies development and implementation for ICT companies should be aware of following issues: that the development and implementation of Green ICT strategies can contribute to the environment, that support for overall sustainability development, that support for the growth of the economy both in the short and the long term, and that the demand of natural resources can be reduced (which reduces business costs).

Moreover, in the context of the real word, based on the result of “Three Analyses” of SSM, they also need to consider these issues:

1. Due to the continuous growth of the popularity of Green ICT issues around the world, many governments have become supporters and facilitators for the development and implementation of Green ICT strategies in firms and organizations.

2. With of the rising awareness of public regarding a “Green” concept in terms of disposal and recycle ICT equipments, having appropriate Green ICT strategies developed and implemented can gain reputation from the public so that generate economic profit.

3. Green organizations trend to support the implementation of Green ICT strategies in ICT companies, because of a “Green” world that is their working objective. Such organizations are very likely to cooperate with the government and also affect the ways in which regulations are formed. Moreover, some organizations that have “Green” values can also act as supporters and technically help Green ICT strategies being developed and implemented, such as some industry associations (e.g. IEEE and GeSI).

4. ICT scholars are pioneers in Green ICT research and practices. They are resources for solutions and ideas for Green ICT strategies to be developed and implemented.

Furthermore, many research articles have reflected the necessity of improving and implementing Green ICT strategies. The level 1, 2 and 3 models and Table 15 are the source of the real world issues and relevant solutions, and they will be helpful to be considered by the practitioners for Green ICT strategies and police development and implementation for ICT companies.

In all, it is recommended that the above issues be considered when a practitioner is developing and implementing Green ICT strategies in an ICT leasing company within this specific scope for this research with the “Roles” as defined by SSM. Theoretically speaking, although it can provide insights to the issue, the result of this research cannot be generalized into other situations.

6.2 **Chapter Summary**

The research is concluded in this chapter. The final stage (stage 6) of SSM is addressed (see figure 27, page 77). In this stage, a list of recommendations that contribute to the
development of systemically desirable and culturally feasible solutions is proposed. Furthermore, a model for the development of specific solution is constructed for the relevant stakeholders for this research. Due to the nature of SSM, the researcher’s personal reflections about this research as a learning process is discussed in the next chapter.
7 THE RESEARCHER’S PERSONAL REFLECTION

As Checkland (2006) describes:

“SSM is an approach which, in use, enables those taking part to learn their way to agreed action which they perceive will ‘improve’ the problem situation, it is a consciously organized process of inquiring and learning…” (p. 1)

Figure 50 is a sense-making model for SSM practice. It shows that SSM as a learning process which entails four primary activities: find and explore the problem situation; construct relevant models of purposeful activity; the models built are used to question the real world in order to define feasible and desirable purposeful action; taking and implementing the agreed action (Checkland & Winter, 2006).

Figure 50: Sense-Making Model for SSM Practice

Thus in this section, with this application of SSM, the researcher is writing about his reflection about what he has learned from this research at the end of this thesis.

7.1 ABOUT THE RESEARCH TOPIC

The researcher realized that the issues of Green ICT are highly complex with numerous factors connected and interacted with each other. In the literature review chapter, the researcher has developed three models (see figure 1, 7 and 8) to illuminate the complexities of the issue, which links starting from the central element – “ICT”, and establishes and scatters these links across economy, business, society, education, government, and the natural environment, and they returns back to “ICT”. From a
systems perspective, the level 3 model (figure 8) clearly tells us the issues of Green ICT are nothing but a system of interconnected factors with a large number of loops that the impact of the central element can return to the centre of the system through these loops. There are examples shown in the literature review chapter (see figure 23, 24 and 25). Thus, the researcher suggests that when Green ICT policy makers develop their Green ICT strategies (especially government strategies), a holistic thinking with the considerations of the impacts on many other sectors (see the level 3 model, figure 8) by adopting systems approach is necessary. Likewise, for any relevant solutions, the implementation should also follow a systems process, so that the impacts between factors can be targeted when implementing.

During the data collection phase, the researcher has had communication with the five participants: ICT leasing company manager, the ICT scholar, the waste management advisor from NZ government body, the green organization spokesperson for ICT issues and the institution IT manager. It is interesting to see that most of the participants have a level of understanding to and are interested in the issues regarding ICT and sustainability. This let the researcher realize that, within this data collection scope, the intention of going “Green” with ICT involved is solid and with this common intention form these five participants, it would be feasible to adopt a systems approach, and develop and implement Green ICT strategies with the cooperation and the desire of all the participants.

Through analyzing the data, the researcher has had the “three analyses” of SSM (see section 5.2 – 5.4) that were conducted as a preparation for developing systemically desirable and culturally feasible solutions for this problematical situation. Then participants’ answers are formulated and then mapped onto the level 3 model that has been constructed in the literature review section. The researcher has developed a deep understanding of the issues of developing Green ICT strategies within a context of these five participants involved.

Finally, the researcher developed a list of recommendations for Green ICT development for the participants. The researcher then realised that it is necessary to develop a model for specific solution development, thus a general model for developing Green ICT strategies specifically in the respective situation of participants is proposed based on Soft Systems Methodology.

7.2 ABOUT SOFT SYSTEMS METHODOLOGY
The researcher has a technical background. In the earlier stage of this research, the researcher experienced difficulties in understanding the philosophy of SSM, as well as how the methodology works. However, in constantly reviewing relevant literature, discussions with the supervisor, and in adopting SSM into practices, answers emerged naturally and questions regarding the methodology were solved through practices. Later, there were larger difficulties in adopting SSM to this particular research scope. At that
time, data collection had been finished, thus it was not feasible to go back and re-interview participants as this was outside the original research design. But the researcher had a new idea: essentially, as Checkland (2010) mentioned, SSM is a learning cycle that “… works with the idea of finding an accommodation among a group of people with a common concern. (p. 229).” Therefore, the researcher decided to further apply and tailor SSM on a higher level, which is more holistic than the scope that SSM has been described by Checkland (2010): “Stories of SSM use come from all sizes of company from small firms to large corporations, from organizations in both private and public sectors… (p. 193).” – on a level that is higher than a concept of an “organization” or “corporation” – within collection of interconnected group of stakeholders who have a common concern on a same issue, instead of within a physical organization. Moreover, in order to apply this new idea, the researcher redesigned the research process (see figure 30). Eventually, the research results produced looked reasonable and relevant to the five stakeholders and to the problematical situation. The three models (figure 1, 7 and 8) and the solution development models (figure 49), with the list of recommendations, are a set of tools for the stakeholders to develop their specific solutions for Green ICT issues or work as guidelines. In all, in the researcher’s opinion, this is a successful research, the researcher has developed a deeper understanding about these issues.

7.3 FURTHER RESEARCH
It has been discussed in section 3.9 that one of the limitations in this research is that there was a lack of engagement with participants. Thus, further research may include discussing those models and recommendations that have been produced from this research, so that the researcher could have a study of the participants’ respective situations and develop specific solutions for each of them base on the existing results of this research.

The learning cycle of SSM is an iterate process rather than a linear one (Checkland & Poulter, 2010, p. 193). Once action is taken for improving the problematical situation, it will bring change to that situation, so that the learning cycling could in principle start again (Checkland & Poulter, 2010, p. 193). Thus the learning cycle of SSM can be seen as a endless process (Checkland & Poulter, 2010, p. 193). Therefore, further research for the topic of the research can be conducted after implemented solutions and the SSM process could start again.

Furthermore, due to time limitation, the model construction work in the literature review chapter is insufficient. There are still a lot more factors that have not been identified and merged into the three models (see figure 1, 7 and 8). Thus further research can be conducted in targeting to enrich the existing holistic models built from this research, for instance adding more elements, define more connections between elements, or focusing on specifying sub-systems from the holistic model (figure 8) and to study them individually based on different requirements and interests.
APPENDIX A: QUESTIONNAIRE

This questionnaire will help me to collect data for my Master of Computing thesis on:

"Information System solutions for implementing Green ICT (Information and Communication Technology) strategies in ICT leasing companies."

COMPLETING THIS QUESTIONNAIRE MEANS THAT YOU ARE GIVING YOUR CONSENT TO MY USING YOUR RESPONSES ANONYMously IN MY RESEARCH REPORT (THESIS).

The time for you to complete this questionnaire will be approximately 15 minutes.

Part 1 Demographics

1. Which type of organization you work for?
2. What is your position in your organization?
3. How many years you have worked in your field?
4. To what degree do you think you understand “Green ICT” strategies?

Part 2 CATWOE

1. Who would be the benefited or harmed (the impact maybe positive and negative to someone or a group of people) of implementing "Green ICT" strategies in ICT leasing companies for recycling? Anyone you can think of?
2. Who (the actor, someone in the company) do you think would usually implement “Green ICT” strategies in ICT leasing companies for recycling?
3. How should ICT leasing companies revise or improve their ICT strategies in order to transform their conventional strategies into "Green" strategies for recycling?
4. How is the implementing of "Green ICT" strategies meaningful to you? Why should we do it? In other words, what are your views on it?
5. Who (individuals or groups of people, a name of a role, not name for a specific individual or organization) could stop the implementation of "Green ICT" strategies in ICT leasing companies for recycling?
6. What are the outside constraints (e.g. economic, political) that could hinder or even stop the implementation of "Green ICT" strategies in ICT leasing companies for recycling?
Part 3 External Factors

1. What impacts do you think the implementation of "Green ICT" strategies could have on: (Please use a few of words, Verb + object, e. g. increase productivity, mitigate climate change)?

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APPENDIX B: INFORMATION SHEET

Information for Participants

Information System solutions for developing and implementing Green Information and Communication Technology (ICT) strategies in New Zealand ICT leasing companies for recycling.

Tena Koe, Talofa Lava, Hello!

I am a Master of Computing student at Unitec. My name is Bing Qian Zhang. I invite you to participate in the research. I am conducting for my Thesis about “Information system solutions for implementing green Information and Communication Technology (ICT) strategies in New Zealand ICT leasing companies for recycling”. The data for this research will be collected from an online questionnaire. This research has been approved by Unitec’s ethics committee in order to prevent any inappropriate actions which could be harmful to the participants.

Your views on “Green ICT” strategies
The objective for collecting data from you is to find out your views on developing and implementing green ICT strategies in the ICT disposal industry in New Zealand. Some demographic information is also required in order to support the main data.

Your participation
An electronic questionnaire has been developed for you to complete. It will be emailed to you by my contact person in your organization and you will email it to that person after completion, so that your anonymity is preserved. The questions in the questionnaire are mainly about your views and opinions about the Green ICT strategies. Please feel free to have your voice. The published research will be available for you to read (contact the researcher).

This questionnaire will probably take 10 minutes for you to complete. All the features that could identify you will be carefully removed when analysing data and your responses will be kept in a secure place.

Confidentiality
Your name and information that may identify you will be kept completely confidential. All information collected from you will be stored on a password protected file and the only access to your information is yourself, me and my two supervisors. Because the questionnaire is anonymous we will not be able to withdraw your data once submitted.
Appendix B

Please contact me if you need more information about the research. At any time if you have any concerns about the research project, you can contact my supervisors:

Professor Kay Fielden, at Unitec, Phone No.: (64) (9) 8154321 x8496
Dr Donald Joyce, at Unitec, Phone No.: (64) (9) 8154321 ext 6065

Thank you!

This study has been approved by the Unitec Research Ethics Committee from (2010) to (2011). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretariat (Ph: 09 815 4321 ext.6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
10 Appendix C: The Process of SSM

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APPENDIX D: PUBLICATIONS FROM THIS THESIS


## LIST OF REFERENCES


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Dawson, C. (2008). The environmental benefits of virtualization: The mere existence of virtualization is more important than the specific type of virtualization. *Virtualization, 1*(3).


