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Information Technology: Impacts on Environment and Sustainable Development

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ABSTRACT

In this modern world, Information Technology gives impacts on society, countries, economy, and environment. This paper discusses the positive, negative, direct and indirect impacts of IT on environmental issues. A strategy for sustainable development in ICT and its future demand are also proposed. Apart from that, a research was also done to find a quantitative indicator to show the relationship between demand in IT industry and impacts to the environment. By using a mathematical formula, an estimation of the effect to the environment can be found. By using the indicator, it is hoped that society and the IT industry will become more aware of their action to the environment.

Keywords: Environment, impact, information technology, sustainable development.

INTRODUCTION

Information technology (IT) is one of the important aspect that makes the world as it is now. The role of IT in our daily life is very important as our quality of lives and the way we live tremendously depend on IT. This happens especially due to the rapid development of IT and its products. It has become essential in our daily life, and the IT industry has given significant impacts to our technical development. Most of the impacts to the environment are negative. In Information Technology, we will discuss in details the effects of Information Technology towards the environment.

As IT and the effects to environment are interconnected in many ways, society has to learn how to change this negative relationship into a positive one. Hence, the study proposes sustainability development that can help to balance and offset the bad effects of IT industry on the environment. In addition, the meaning of sustainable development and the challenges to be overcome to sustainability in IT industry will also be discussed in Environmental Impacts of Information Technology. After that, an approach to discuss further how the qualitative effect of the environment will also be suggested by using the formula and method

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derived. The formula will later be proven by using a set of data, which depict the relationship between demand (for the purpose of this paper, demand indicate demand of electricity), gain and loss of a certain processes, and these will be discussed in Sustainable Development. Finally, some effective ways to reduce the environmental impacts will be put forward in *Sustainable Development in ICT*.

INFORMATION TECHNOLOGY

The phrase Information Technology (IT) refers to an entire industry. The phrase information technology carries the definition of the use of computers and other gadgets (such as phones) and software to manage information. In some companies, this is referred to as Management Information Services (MIS) or simply as Information Services (IS). The information technology department of a large company is responsible for storing information, protecting information, processing the information, transmitting the information as necessary, and later retrieving information as necessary (Schneider, n.d.).

ENVIRONMENTAL IMPACTS OF INFORMATION TECHNOLOGY

Information technology like many other creations, gives impacts to the society, economy and most importantly, the environment. The impacts information technology has can either be positive or negative and direct or indirectly harm effects to the surrounding. Below are the impacts of Information Technology.

First Order Impact

The first order impacts of Information Technology mostly give direct effects towards the surrounding. Among the impacts that are rated as the first order are the manufacture of IT equipment such as computers, mobile phones, peripheral devices and satellites. Inside these products, there are various additional components used to produce IT equipments. Most manufacturing processes of these components pollute the environment. One of the examples of the pollution is the production of semiconductors that releases dangerous gases to the atmosphere such as acid fumes (Berkhout & Hertin, 2001). According to Hilty and Ruddy (2000) in their paper entitled, 'Towards a Sustainable Information Society', only 2% of the materials used in the production of personal computers become parts of the product. The remaining (98%) are dumped as wastes.

The second direct impact that is rated as the first order impact is the transportation of components and products of IT. Most of the components used for production of IT equipment come from all over the world. These components are imported to an assembly centre to assemble the products. After the production is done, the final IT products are exported to other places. The transportation process of IT equipment production will leave a significant carbon foot print that harms the environment.

Another direct first order impact is the consumption of energy by the ICT equipment. The increasing demand and supply for ICT devices increase electrical consumption. The increase in power consumption can cause more carbon foot print to the environment.

Last but not least, the direct impact of IT is the ever increasing amount of electronic waste (e-waste) that comprises old and considered outdated electronic devices. These devices are disposed off when the owners buy new and more advance equipment. Improper e-waste management will lead to pollution due to leak of lead, mercury and other toxic materials from the e-waste to the landfill. For example, cathode ray tubes if leaked will release heavy metal leaching to the ground water and harm the water source.

Second Order Impact

The second order impacts of ICT industry are mostly positive to the surrounding. Most probably come with the fact how ICT development is managed to increase the economy via the use of information technology. The growth in economy is due to the change to utilise ideas compared to energy and material (Kelly, 1999). For example, the growth of economy in the United States in 1995-1998 was because of IT related businesses (Kelly, 1999). Other than that, IT also managed to change the way product and service is designed, produced, distributed and operated. The technology managed to do a simulation of these processes and thus give insights into the end results of the processes even before they are started. Via the usage of IT, the cost to complete these processes can be reduced significantly. Below are some detailed examples of how ICT can improve the processes of making products:

- Intelligent production processes: Through careful computer-aided design of production facilities and precise control of operations during production made possible by extensive sensors and automated controls.
- Intelligent design and operation of products: enabled by computer-aided, simulations of product performance result in 'lighter' products that use less materials to make them operate more efficiently; efficient sensors and controls ensure services/ functions are delivered efficiently when and where they are required.
- Reorganisation of supply chains and business organisation: E-commerce leads to the closure of retails outlets, more efficient inventory and chain management supply, and the rise of tele-working.
- The process of e-materialisation: The substitution of tangible goods for intangible services (for instance, the purchase of e-book rather than book or the purchase of music online rather than music CDs).

In conclusion, the IT industry has many impacts on the environment. Unfortunately, none of them gives a qualitative indicator that is used to evaluate the relationship between the demand and the impact of IT on the environment. This finally brings to this research which is intended to find a relationship between the three aspects and to provide a qualitative indicator on how the demand of IT industry affects the environment. With this clear, concise qualitative indicator, it is hoped that the industry will respond better to numerical indicators in terms of realising the importance of sustainable development in the IT industry.

SUSTAINABLE DEVELOPMENT

There are many definitions of sustainable development, including this landmark one which first appeared in 1987:

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

This was taken from the World Commission on Environment and Development's report entitled, 'Our Common Future', which is also known as the Brundtland Report (United Nations, 1997).

Sustainable development is development that meets the needs of the present without compromising the ability of the future generations to meet their own. It contains within it two key concepts, namely:

- 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 the present and future needs.

Thus, the goals of economic and social development must be defined in terms of sustainability in all countries - developed or developing, market-oriented or centrally planned. Interpretations definitely vary but they must share certain general features and flow from a consensus on the basic concept of sustainable development and a broad strategic framework for achieving it. Development involves a progressive transformation of economy and society. A development path that is sustainable in a physical sense could theoretically be pursued even in a rigid social and political setting. Physical sustainability, however, cannot be secured unless development policies pay attention to such considerations such as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation.

CONCEPT OF SUSTAINABLE DEVELOPMENT

According to the Brundtland Report, sustainable development aims to meet the basic needs of all people and provide all opportunities to everyone so that they can satisfy their aspiration for better life. This is because the main objective of development is to satisfy the basic human need. The basic needs especially in the developing countries are food, clothing, shelter and jobs, satisfaction of human needs and aspirations in the major objective of development. The report also claimed that a world which in which poverty and inequity are endemic is susceptible to be ecological and other crises (United Nations, 1997). Below are detailed explanations of sustainable development concept adapted from Brundtland Report:

- Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability. To achieve sustainable development, society has to promote consumption standard that are within the limit of ecological possible and to which all can reasonably aspire.
- Sustainable development will compete to make sure that societies meet human needs both by increasing productive potential and by ensuring or providing equitable opportunities for all.
- Sustainable development can only be pursued if demographic developments are in harmony with the changing productive potential of the ecosystem.
- To achieve sustainable development, human activities at minimum must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings.
- The accumulation of knowledge and the development of technology can enhance the carrying capacity of the resource base. But ultimate limits there are, and sustainability requires that long before these are reached, the world must ensure equitable access to the constrained resource and reorient technological efforts to relieve the presume.

* The points discussed above are taken and adapted from the Brundtland Report.

SUSTAINABLE DEVELOPMENT IN ICT

Sustainable development has increasingly become important to all sectors especially business. Overuse of natural resources to meet ever increasing demands has shown its toll to the world we are living in right now. The rapid depletion of resources, as well as the negative impacts as a result of the need to fulfil demand of societies, has made the societies and corporate sector realise the importance of sustainability in their own industry. As such, more recently, a perspective has emerged that defines sustainability to include three components, namely, the natural environment, society, and economic performance. These components are mostly known as the triple bottom line (TBL). The TBL approach proposes that besides economic performance, organizations need to be aware of their act in activities that will give positive effect to the environment and the society. This TBL approach is a crucial to be used in all industries, especially in ICT (Dao, Langella, & Carbo, 2001).

Parallel to the new technology being introduced to our lives, the ICT sector has managed to give a big impact and change the way we live, communicate, work, learn and play. From mobile phones, tablets and micro-computer chips to the internet, ICT has successfully provided us with innovative products and services that are now becoming parts of everyday life. Unfortunately, the ever growing quantities of these innovative IT products and peripherals have made more wastes resulted from discards of old, broken IT products. As the demand for IT products and services increases, the data will also increase. This data and information require physical storage and hence access to reliable electricity to power up the servers that keep the data. These data centres have grown in number due to increasing demands hence making the data centres as the ‘factories’ of this century [1]. Fortunately, these ‘data factories’ do have a

choice to power the centres unlike the factories during the Industrial Revolution that relied heavily on coal-source energy generation. The ICT companies can opt to determine the kind of energy they use to power up their data centres.

CHALLENGES OF SUSTAINABILITY IN ICT INDUSTRY

As many other good things in the world, there are many challenges to be faced in order to achieve sustainable development in the ICT industry. Below are some of explanations of these challenges.

Bad Decision Making Favouring Profit over Effects to the Environment

With the development of technology, people can opt to keep their data online rather than wasting more money to keep them using their own storing devices. This step helps to reduce the additional need for peripherals such as flash drives or hard disk drives. Unfortunately, the step that is hoped to reduce significant usage of the IT products that may lead to less amount of e-waste produced will also have effects in increasing the energy used to power the data centres as more people keep their data online. The term cloud, or cloud computing, used as a metaphor for the internet, is based on an infrastructure and business model, whereby rather than being stored in your own devices - data, entertainment, news and other products and services are delivered to your device, in real time, from the Internet (Kelly, 1999).

As mentioned above, powering these massive storage facilities requires huge amounts of energy. Fortunately, with the technology that we have now, the energy source to power these data centres can come from a greener, renewable energy source. However, the decisions on how the cloud will be built are being made by business leaders who are more concerned with the higher cost of using renewable energy rather than the effects of using dirty energy that they prefer using on the environment. In January 2010, for example, Facebook built a new data centre in Oregon which is powered by PacificCorp, a utility that gets the majority of its energy from coal-fired power stations, the United States' largest source of greenhouse gas emissions (Greenpeace International, 2010). This act is one of the proofs how some IT companies are more concerned about money than the environment when they choose to power up their data centres with the cheapest electricity means available, which in many countries means dirty coal. Below are the data for carbon footprint produced by data centres that uses dirty energy (see Fig. 1).

In the graph above, it is clear that if cloud computing is a country, it would have been the fifth highest country in the world with high electricity consumption, making it one of the highest contributors of carbon footprint. In conclusion, the IT companies play a vital role and have to live up with it to reduce their carbon footprint in the ICT industries by making a wiser decision that will mostly benefit the world and the environment in the long run.

Lack of Awareness in the Society

Another challenge towards sustainable development in the ICT industry is the lack of awareness in a society. This happens when the society especially the consumers do not care enough about

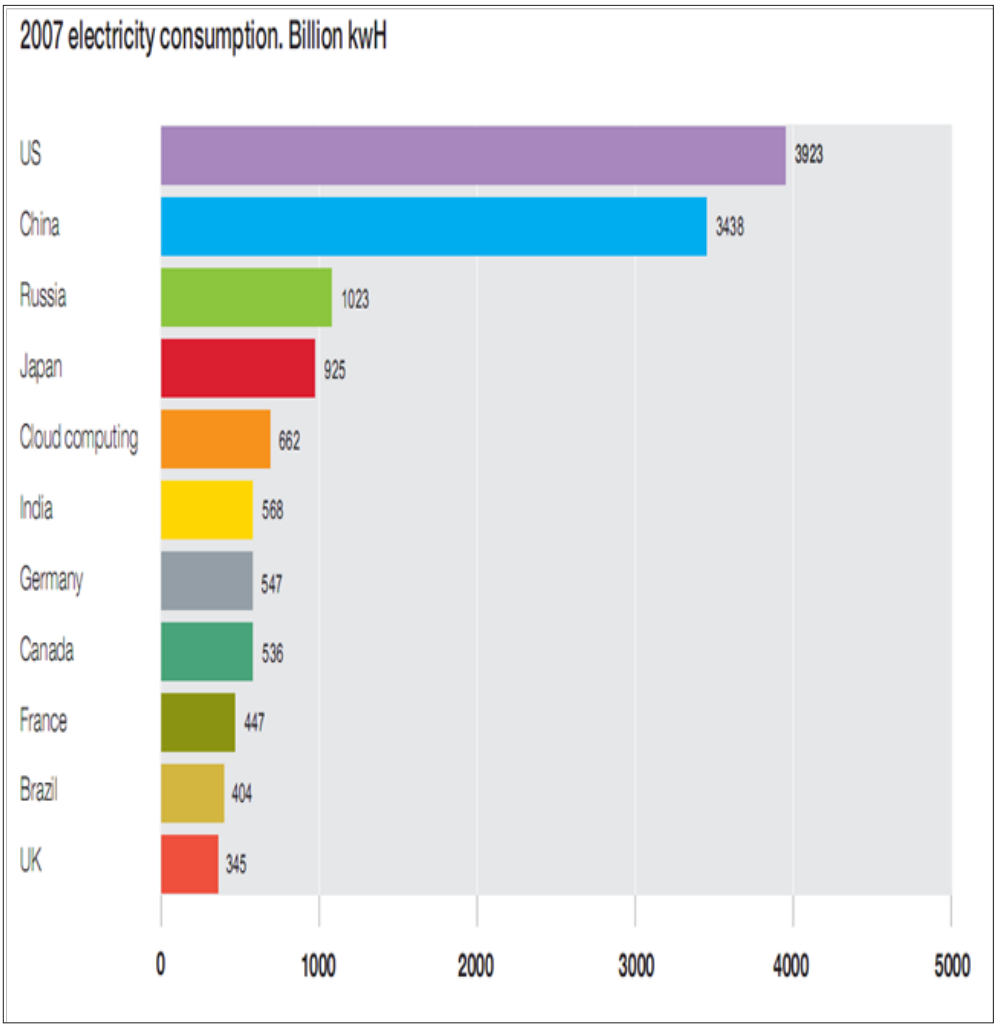

Fig.1: 2007 Electricity Consumption,billion kwH (Greenpeace International, 2011)

the consequences of the excess usage of IT products and peripherals, as well as the excessive usage of energy to power them. This can be overcome when the society is educated about the dangers and the effects of the problem mentioned above. The society must realise that everytime they change to the latest gadgets, the act will lead to increases of e-waste. Hence, the government and private bodies have to educate the people about this danger.

DISCUSSION AND SUGGESTIONS

As explained earlier on, human activities and industries, such as the IT industry, give impact to the environment. In the case of the IT industry, there is not much we can do to eliminate all the impacts on the environment. As a responsible society, however, we should at least try our best to minimise the effects of our everyday activities while using and managing information and IT devices. In this section, we will try to look at the energy purchased by IT companies to manage their data centres.

While some companies opt to make good decisions by using renewable energy, there are many other IT companies that prefer to save their money by using dirty energy powered by coal burning. To see how certain acts of these companies benefit the quality of environment, a new formula is derived. The formula is E=(d*g)/l, where E refers to quality of the environment, d refers to demand of the IT industry (in this case, only the electric demand to power data centres is considered), g refers to gain added to the benefit of the environment (here, g refers to clean energy used to power the data centres) and l refers to the loss that impacts the environment (here, l means the dirty energy used to power data centres). The derivation of this formula is shown in details as follows:

Derivation of the Formula

$$E \; 1/(NR) \quad [1]$$

$$E = x / (NR) \quad [2]$$

From the equation above, "x" considered to be the constant, which is considered to be the gain of the system. In this case, gain refers to the per unit consumption of the entity, namely, electricity, without causing any harm on the environment. As indicated earlier, the source of clean energy is considered to be the clean energy, assuming the source used is hydro electricity, which does not cause immediate harm to the environment. "NR" is considered to be a natural resource, using which we generate the electricity. If we consider 'x' to be our gain, the equation can then be rewritten as:

$$E = g / NR \quad [3]$$

$$E / g = 1 / (NR) \quad [4]$$

On the other hand, from the equation above "y" is considered to be the constant, which is the loss of the system. Here, loss refers to the per unit consumption of the entity, i.e. electricity, with causing any direct harm towards the environment. The source of dirty energy is known and considered as the non-environmentally friendly energy, assuming the source of electricity used is coal/petroleum/nuclear, etc., which cause immediate harm to the environment. "NR" is considered to be the natural resource, using which the electricity is generated. If 'y' is considered as our loss, the equation can therefore be rewritten as:

$$d \; 1/NR \quad [5]$$

$$d = y / NR \quad [6]$$

If 'y' is considered as our loss, the equation can thus be rewritten as:

$$d = l / NR \quad [7]$$

$$d / L = 1 / NR \quad [8]$$

From equations 8 and 4, we can conclude that:

$$d / l = 1 / NR = E / g \quad [9]$$

The equation can be rewritten and represented as follows:

$$E / g = d / l \quad [10]$$

Hence, the formula is:

$$E = (d.g) / l \quad [11]$$

As the quality of environment, E, is proportionate to both gain added to the environment, g, and the demand, attempt to reduced the demand must be done (Table 1).

TABLE 1: Demand of electricity for various companies

Companies	Demand of Electricity, d(*MW)	Dirty Energy Used , l(*MW)	Clean Energy Used, g(*MW)
Amazon	98.05	84.41	13.64
Apple	146	134.79	11.21
Dell	12	5.24	6.76
Facebook	307	196.61	110.39
Google	564	341.87	222.13
Hp	172	148.03	23.97
IBM	99.5	88.09	11.41
Microsoft	252	177.43	74.57
Oracle	19	17.74	1.26
Rackspace	44	30.49	13.51
Salesforce	11.5	11.04	0.46
Twitter	7	5.51	1.494
Yahoo	74.2	35.07	39.13

RESULTS

Below is a graph depicting the trend of electricity demand and also the trend of the uses of clean and dirty energy. As shown below, the trend of dirty energy used to fulfil the demand of electricity is higher than the trend of the clean energy used (Fig. 2).

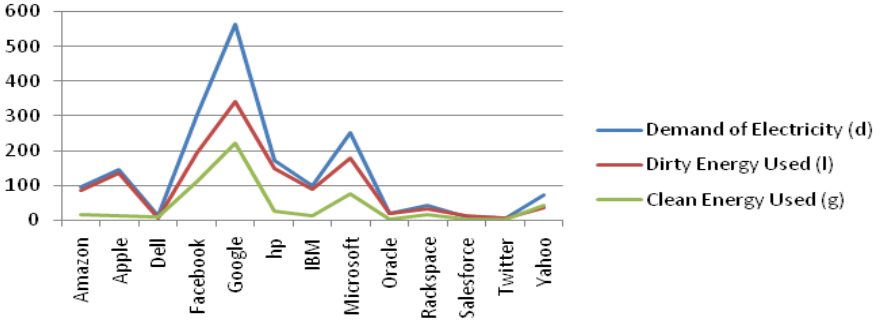

Fig.2: Demand of Electricity and Trend on Type of Energy Used

Next, depicted below is the result of effect on the environment with respect to demand. What can be seen is the higher the demand, the higher the effect will be on the environment. E is an indicator that can be used by companies to measure how much or how high they can affect the environment. Hence, to reduce the effect to environment, the demand of electricity must also be reduced. Below is the calculation of E=dg/l based on demand (Table 2).

TABLE 2: Calculation of E=dg/l based on demand

Companies	Demand of Electricity /MW	Effect to Environment
Amazon	98.05	15.84
Apple	146	12.14
Dell	12	5.24
Facebook	307	172.37
Google	564	366.46
hp	172	27.85
IBM	99.5	12.89
Microsoft	252	108.98
Oracle	19	1.35
Rackspace	44	19.5
Salesforce	11.45	0.48
Twitter	7	1.9
Yahoo	74.2	19.32

The graph below is a representation of the trend in the demand for electricity and its effects on the environment. The graph is the results generated from Table 3. Here, it can be clearly observed that the effect to environment follows the same trend as the demand for electricity. This further clarifies the relationship between them (Fig. 3).

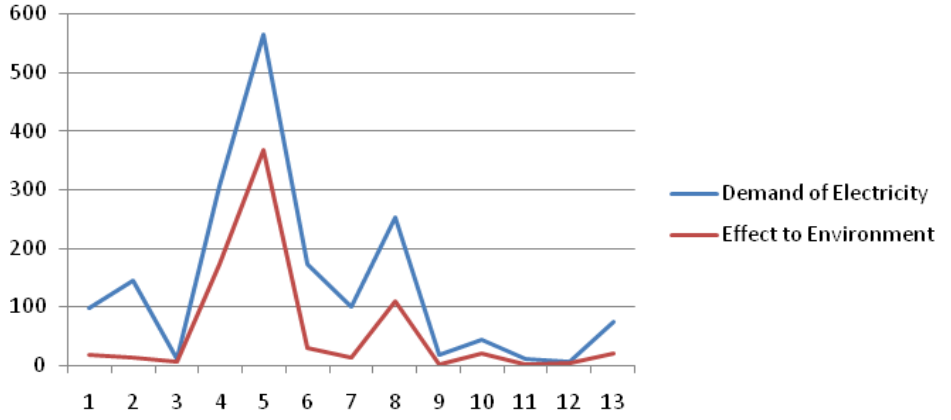

Fig.3: Trend of demand of electricity and its effect to environment

Figure 4 is a representation of the graph based on the relationship of the demand for electricity and its effect on the environment. Figure 5 depicts the relationship between the two variables, with the demand of electricity as the independent variable and the effect to the environment as the dependent variable. It can be seen that the effect on the environment increases linearly with respect to the demand for electricity.

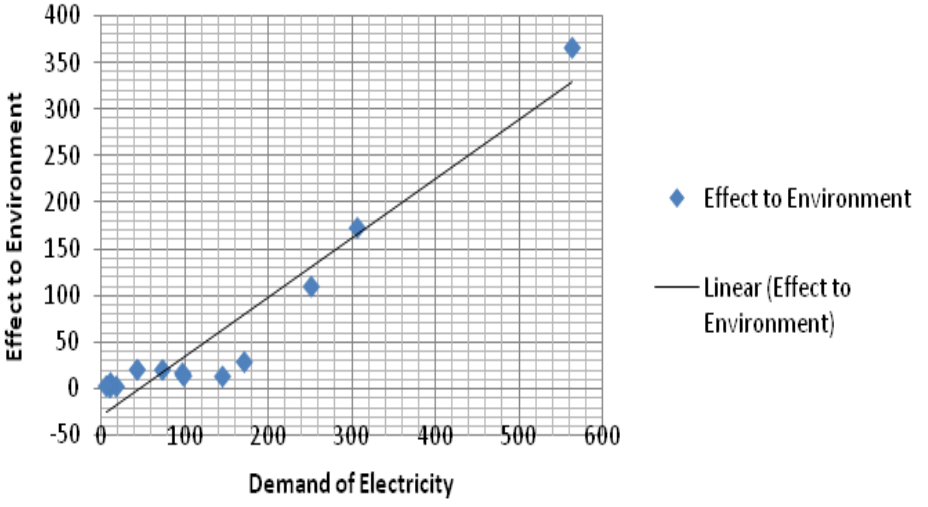

Fig.4: Relationship between Demand Of Electricity and Effect to Environment

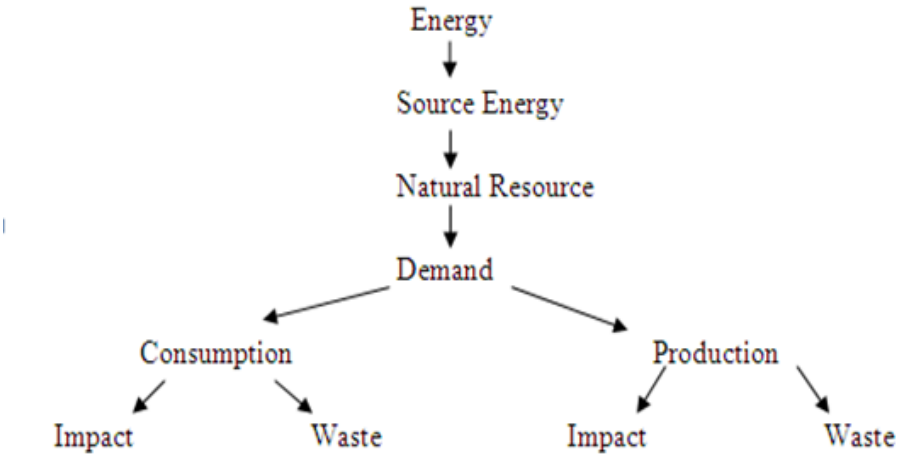

Fig.5: The Representation of Energy Distribution, Recycling and Production of Resources

Lastly, the chart provides a flow of relation between the demand and its impact, particularly to the environment. As shown, the demand leads to production and consumption of a product.

As explained earlier, the products here mean the ICT devices and peripherals plus energy used in the production, consumption and managing the wastes of the ICT industry. As a result of the demand, more products are made, leading to more effects to environment. Hence, it is important to emphasize once again that by decreasing demand, the impacts on the environment can be reduced to achieve sustainability.

CONCLUSION

From the data gathered in the previous section, the demand can be clearly and quantitatively shown to have a significant relation with the impact to the environment. Hopefully by using the formula discussed above, the result (i.e. E) can be used as an indicator to signify how much a company in the IT industry affects the environment. It is also hoped that the companies and particularly the consumers can reduce their demands so as to reduce the effects on the environment as the relationship between these two elements has quantitatively been proven in this research.

Besides that, an awareness toward the direct impacts of this relationship should exist in the society. The society, as well as the ICT companies, should make their choice wisely in using resources so that it will be easier to achieve sustainability of the environment. When smart decisions are made, it is possible to reduce the demand for IT products, while sustainable development and progress in the ICT industry can be achieved at the same time.

REFERENCES

Berkhout, F. & Hertin, J. (2001). *Impacts of Information and Communication Technologies on Environmental Sustainability: Speculations and Evidence.* Report to the OECD, Frans Berkhout and Julia Hertin, University of Sussex, United Kingdom.

Dao, V., Langella, I., & Carbo, J. (2001). From Green to Sustainability: Information Technology and an Integrated Sustainable Framework. *The Journal of Strategic Information Systems, 20*(1), 63-79.

Greenpeace International. (2010, March). *Make IT Green: Cloud Computing and Its Contribution to Climate Change*. Retrieved July 6, 2012, from http://www.greenpeace.org/international/Global/international/planet-2/report/2010/3/make-it-green-cloud-computing.pdf

Greenpeace International. (2011, April). *How Dirty is Your Data.* Retrieved July 6, 2012, from http://www.greenpeace.org/international/Global/international/publications/climate/2011/Cool%20IT/dirty-data-report-greenpeace.pdf

Greenpeace International. (2012, April). *How Clean is Your Cloud.* Retrieved July 7, 2012, from http://www.greenpeace.org/international/Global/international/

Hilty, L. & Ruddy, T. (2000). Towards a Sustainable Information Society. *Informatik / Informatique, 4*, 2-9.

Kelly, H. (1999). *Information Technology and the Environment: Choices and Opportunities*. Retrieved July 13, 2012, from www.cisp.org

Pinto, V. (2008). E-Waste Hazard:The Impending Challenge. *Indian Journal of Occupational and Environmental Medicine, 12*(2), 65-70.

Schneider, L. (n.d.). *IT Definition*. Retrieved July 13, 2012, from http://jobsearchtech.about.com/od/careersintechnology/p/ITDefinition.html

United Nations. (1997). *Our Common Future.* Oxford University Press.