Organizational IT sustainability measures: the strategic green ontology

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Abstract
This chapter provides an overview of contemporary measures to improve environmental IT sustainability, and explains how to prioritize these measures.The question is not if, but how and when organizations should be addressing sustainability issues, due to expected growth in regulations and growth in stakeholder pressure. In mitigating these sustainability problems the role of IT is ambiguous. IT as both part of the problem and part of the solution to the problem. This research explains how IT-related opportunities in organizations can support a sustainable environment, and how these relate to organizational goals.

Introduction: IT and sustainability issues
Sustainability is increasingly recognized as an important management subject. The realization that responsible IT usage is a sustainability issue is growing. An example of a threat to both organizational and human sustainability is the dependency on energy, depending on the primary activities of an organization's IT can take up to 50 percent of the total energy usage. (McKeefry, 2008). Thhis describes one of the justifications for Green IT implementation, but also describes the need for environmental awareness. Green strategies provide companies with ways to be more climate friendly. There are multiple motivations for companies wanting to become more 'Green'. Bansal and Roth (2000) collected data that lead them to state that "firms were motivated largely by concerns for legitimacy, less by competitiveness, and even less by ecological responsibility". However, Porter & van der Linde (1995) already recognize that companies who actively pursue a green strategy, compared to only complying with regulations, can gain serious advantages in

terms of costs because it forces them to innovate. They also state: "company mind-sets make the costs of addressing environmental regulations appear higher than they actually are" (Porter & van der Linde, 1995). The usage of IT plays an important role in companies nowadays, which means its role is ambiguous; IT as one of the causes of environmental problems and IT as part of the solution to solving environmental problems. The usage of IT is a big energy consumer, plus the production of IT components uses a lot of energy and environment unfriendly production and recycling methods. A recent study shows that CEOs find sustainability of great importance to the success of their organization, and more than 90% of the CEOs believe sustainability issues should be fully integrated into the strategy and operations of an organization (Accenture, 2010). More than 90% of CEOs state their organization will employ technology to address sustainability issues, leading to a clear business case for IT sustainability investments. The remainder of this chapter will investigate the following research question: *"How can IT-related opportunities in organizations support a sustainable environment and how can these be incorporated into organizational goals?"*

Justifying IT Sustainability investments

It can be hard to justify investments in sustainability if it is unsure how and if these investments are going to be of help to an organization. Whatever the justifications for a corporate responsibility initiative within an organization are, if they cannot be related to the core strategy and operations of any specific organization -or the places in which it operates- its initiatives won't be successful (Esty & Winston, 2006; Porter & Kramer, 2006). An organization's strategy can be described as: "the direction and scope of an organization over the long-term: which achieves advantage for the organization through its configuration of resources within a challenging environment, to meet the needs of markets and to fulfill stakeholder expectations" (Johnson, Scholes, & Whittington, 2008). According to Olson (2008) an ecologically sustainable – or in their research called "Green"- strategy is one that is complementary to the business, operations and asset strategies and helps an enterprise to make decisions that have a positive impact on the environment. Unlike a green strategy, the business, operations and asset strategies are often well developed as a lot of attention has been paid to them. In order to formulate an effective green strategy the basic principles that are the basis of a green strategy should be leading an organization to make decisions based on solid business logic and which make good business sense (Olson, 2008). By applying the steps derived from Porter & Kramer (2006) explained in the next part of this chapter the focus will be on applying the organization's limited resources available on the issues most central to the organization's environmental footprint and reputation. Because the interdependence of business and society is often not recognized most corporate responsibility initiatives lead to uncoordinated Corporate Social Responsibility (CSR) and philanthropic activities that do not connect to the general strategy. These uncoordinated initiatives do not assist the firm in gaining a competitive advantage, or make any meaningful strategic impact.

Porter & Kramer (2006) have developed five steps that are required to develop a good corporate responsibility strategy, and according to Harmon et al. (2010) these steps are also applicable to sustainability in IT. These five steps are a sequential approach that assist an organization in developing a prioritized action plan:

1.)   Identify the points of intersection
2.)   Choosing which issues to address
3.)   Creating a corporate social agenda
4.)   Integrating inside-out and outside-in practices
5.)   Creating a social dimension to the value proposition

1.) Identify the points of intersection: In order to effectively apply sustainability principles within IT, it is important to determine the points of intersection. There are two types of linkages, inside-out and outside-in linkages.

Inside-out linkages are the points where sustainability issues in the normal course of business impact the value chain of the IT organization. At these points the IT strategy impacts the environment. This could include everything from datacenter design, emissions, water use. Outside-in linkages, which are external conditions that influence organizations, indicate where and how the external environment impacts the IT organization in terms of opportunities, constraints, and risks. These factors impact the organization's competitive context (Porter & Kramer, 2006; Harmon et al 2010).

2.) Choosing which issues to address: It is impossible to deal with all the potential sustainability issues that the organization faces as the costs would be too high. The high impact issues that directly intersect with the organizations must be addressed; other social agendas that do not directly intersect with the business are best left to companies in other industries, charital organizations or government institutions (Porter & Kramer, 2006). There are three categories that help prioritize issues:

Generic Issues	Value Chain Impacts	Issues of Competitive Context
Issues that are not significantly affected by an organization's operations nor materially affect its long-term competitiveness.	Issues that are significantly affected by an organization's activities in the ordinary course of business.	Issues in the external environment that significantly affect the underlying drivers of an organization's competitiveness in the locations where it operates.

Figure 1 Recognizing which type of issues to address (Porter & Kramer, 2006)

An example of a generic issue could be shortage of drinkable water in Central Africa. There is not much reason for an average IT organization in an European company that focuses on the European market to volunteer in drilling water wells. The organization has no financial, business or human resource connection to Southern Africa, and businesswise nothing to gain with improving this very specific problem.

An example of a value chain impact of the organizations activities is the excessive energy usage. For an IT organization it is logical that reducing energy usage positively affects the sustainability of its value chain. Issues of Competitive context are the issues that require thinking out of the box. Replacing a lot of paperwork with something like a tablet, e-reader or a laptop seems unlogical as one would assume a 500 euro laptop is a lot more expensive and has a lot more energy usage during its life cycle than the few cents a piece of paper costs. However, how much paper does an average employee use?

3.) Creating a corporate social agenda: A corporate social agenda must look beyond the community's expectations for opportunities to achieve social and economic benefits simultaneously. It must be responsive to stakeholders to mitigate risk, but to provide advantages in the competitive context it must go a step further. To distinguish between where corporate responsibility issues are responsive and when strategic advantage occurs there are two types of Corporate Responsibility (CR) to keep in mind:

i) Responsive to corporate responsibility: Acting as a good corporate citizen, adapting to the evolving concerns of stakeholders and mitigate existing or anticipated adverse effects from business activities. Adressing the Value Chain impacts described in 2.). Responsive sustainability typically deals with generic value chain issues of little or none strategic value to mitigate risk. It does not impact the competitive context.

ii) Strategic corporate responsibility initiatives: Strategic responsibility initiatives focus more on the issues that have impact on the competitive context and transform value chain activities to enhance sustainability while supporting business strategy. This helps distinguish the organization from competitors in a way "that lowers costs or better serves a particular set of customer needs" (Harmon et al., 2010). The initiatives have moved on from good corporate citizenship and mitigating harmful value chain impacts to start a small number of initiatives whose social and business benefits are large and distinctive. This helps unlocking the shared value by investing in aspects of strategic context that strengthen the organization's competitiveness.

Generic Social Impacts	Value Chain Social Impacts	Social Dimensions of Competitive Context
Good citizenship	Mitigate harm from value chain activities	Strategic philanthropy that leverages capabilities to improve salient areas of competitive context.
Responsive CR	Transform value chain activities to benefit society while reinforcing strategy.	**Strategic CR**

Figure 2 Understanding the difference between responsive and strategic CR (Porter & Kramer, 2006)

In figure 6 we can see that, according to Porter & Kramer addressing generic social impacts and purely mitigating the harm from value chain activities does not lead to strategic advantage that is actually requested. In their research Porter & Kramer (2006) describe that the true competitive advantage begins when moving away from being responsive.

4.) Integrating inside-out and outside-in practices: When value chain practices and investments in competitive context are fully integrated CR becomes hard to distinguish from the day-to-day business of the organization. Activities in the value chain can be performed in ways that enforce improvements in the social dimensions of context. At the same time, investments in competitive context have the potential to reduce constraints on an organization's value chain activities. The competitive context here refers to "the quantity and quality of business inputs, the rules that govern competition, the size and sophistication of demand, and the availability and capability of business ecosystem members, especially members of the firm's value chain. The IT organization needs to understand the relationships and the how and where sustainability issues will impact" (Harmon, Demirkan, Auseklis, & Reinoso, 2010).

5.) Creating a social dimension to the value proposition: The most strategic corporate responsibility occurs when an organization adds a new dimension to its value proposition, making sustainability impact integral to the overall strategy. Adding a new dimension to the value proposition offers new possibilities for competitive positioning. Adding sustainability to the IT value proposition can be hard, and to be successful sustainability must be a core dimension of every activity the IT organization does. "For example, a sustainable IT value proposition might include products and services that were developed using processes and materials that minimize their environmental impact. Or, an IT service might enable customers to work collaboratively on demand from any location, thereby minimizing travel and upfront infrastructure costs" (Harmon, Demirkan, Auseklis, & Reinoso, 2010).

Here the focus is changed from responsively mitigating the harmful effects of IT usage, to the realization that investments in IT can help the total sustainability of the company. This requires that full awareness of the problems and requires insight into the competitive position. Not only for the IT department internally, but what the IT department can add to the value proposition of the whole organization.

The Strategic Green Ontology

In order to structure the measures organizations can take to sustain their IT organization, we use dimensions adapted from the Supply Chain Operations Reference (SCOR) model. The SCOR model was developed to "impose a modus Operandi, which unconditionally divides an organization's IT activities into an unending sequence of projects to modify IT services". (Zarnekow, Brenner, & Pilgram, 2006) This model is used to describe the relevant scope and key activities of IS management, aiming at the whole IS management discipline. This model has also been adapted for sustainability by adding a return process into the supply chain operations. (Schmidt, Erek, Kolbe, & Zarnekow, 2009). The original SCOR model is aimed at industrial management; it has also been transferred to IS software and IS service providers by Zarnekow et al (2006). These dimensions are expanded in the remainder of the chapter, and the structuring of measures that operationalize the dimensions in Figure 3 both integrates and extends current literature. The Strategic Green Ontology (SGO) offers an organizational perspective instead of a technical perspective as found in the research by Murugesan (2008). The SGO is also compatible with existing measurement structures on the subject.

The Strategic Green Ontology (SGO) in Figure 3 shows that sustainable IT within organizations can be divided into (1) Govern, (2) Source, (3) Make and (4) Return dimensions. In turn, the Govern dimension can be further specified into (1.1) Growth options, (1.2) Location, (1.3) Organizational policies, and (1.4) Responsibilities.
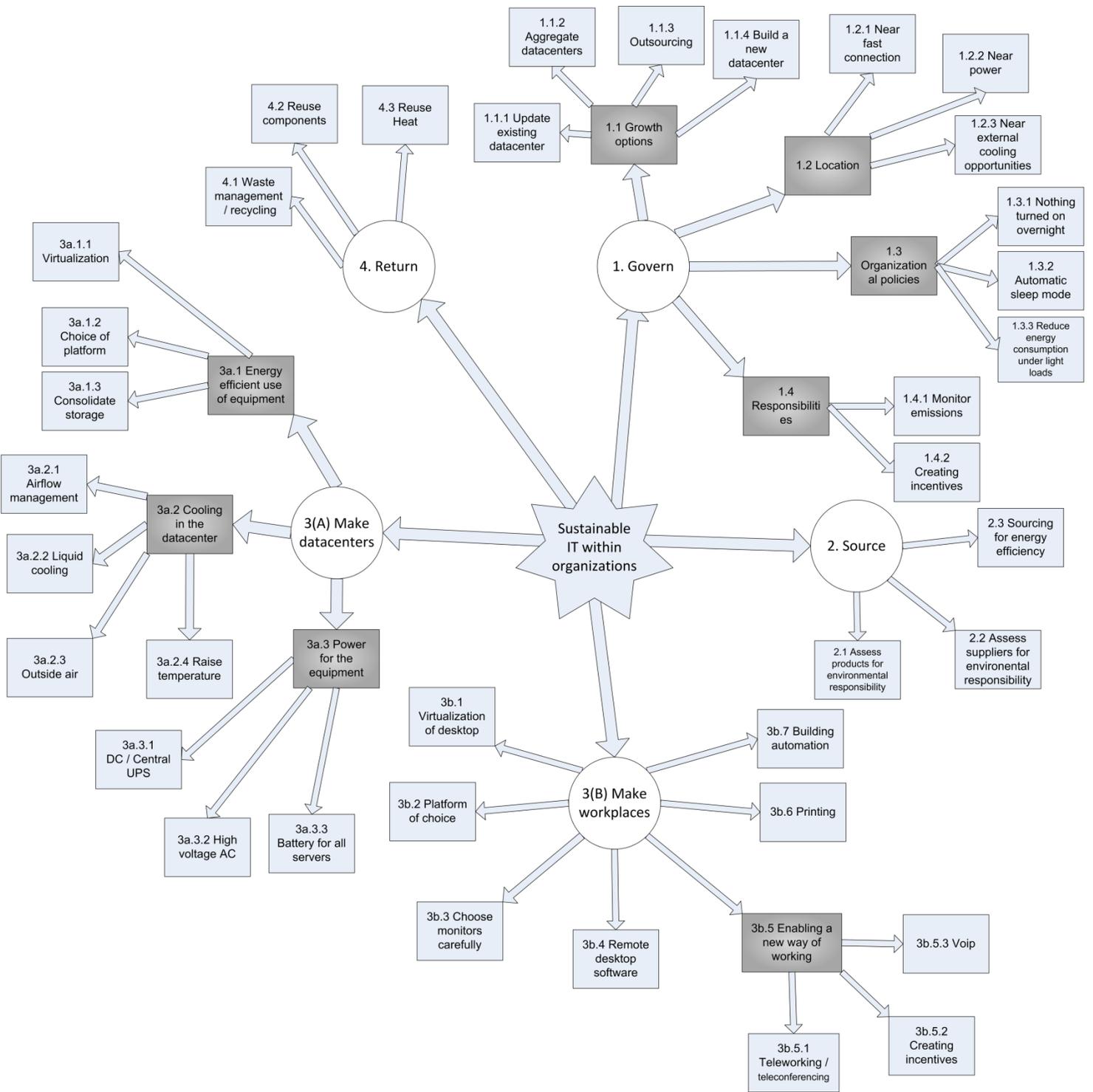
Figure 3 The Strategic Green Ontology (SGO)

We have identified four available Growth options within the Govern dimension: (1.1.1) Update existing datacenters, (1.1.2) Aggregate datacenters, (1.1.3) Outsourcing, and (1.1.4) Build a new datacenter.

1.1.1: *Update existing datacenters*

With retrofitting green IT opportunities it is often possible to enlarge the capacity of existing datacenters, preventing the need to build a new one. An update of the existing datacenters is not in all cases possible, or a smart business decision. If an expensive revision of the existing datacenter does not provide the growth opportunity that is required (for example the expected growth is higher than the expected capacity growth) than a new datacenter or (partial) outsourcing might be a better idea (Spafford, 2009).

1.1.2: *Aggregate datacenters*

If there are multiple datacenters that require updating, or when that's impossible, it could be a wise business decision to aggregrate these datacenters into one big, possibly new datacenter where all state of the art green opportunities are included right from the start, and where the "datafloor" is designed with future greening possibilities in mind. "The first approach is to identify improvement opportunities in the existing data center(s) and prioritize improvements based on costs and benefits – both in terms of risk reduction and true hard accounting cost benefits." (Spafford, 2009)

1.1.3: *Outsourcing*

Another possibility is (partial) outsourcing, for example the colocation of servers to firms that have the resources necessary to host the servers in question. Traditionally this should be done on the basis of technical and business requirements while also factoring in costs and risks, however, greenness could also be taken into account. Another outsourcing option is renting dedicated servers, servers hosted and maintained by third parties. If there is not that much computational horsepower required virtual private servers can be an option, this means hiring one or more virtual machines on a server maintained by a third party. A step further could even lead to hosted application solutions, here the management of the applications does not happen within the organization, but is bought as a service, and the organization that is offering these services can probably do this more efficiently due to economies of scale.

1.1.4: *Build a new center*

If there is the opportunity to build a new data center, completely from scratch this presents the opportunity to consolidate under-utilized data centers, and apply the newest efficient technologies. Of course this new datacenter should, when possible, also be built in an area where there is cheap renewable energy, and where the climate enables the datacenter to be cooled with outside air throughout the biggest part of the year. Building a new datacenter can be a costly

operation but the savings compared to having two datacenters based on older technologies can be substantial (Spafford, 2009).

We have identified three ways to improve sustainability by keeping the location in mind: (1.2.1) Locating near fast connections, (1.2.2) Locating near power, preferably renewable energy sources, (1.2.3) Locating near external cooling opportunities.

1.2.1: *Locating near fast connections*

It might be worth further investigating if it is possible to dynamically assign loads based on availability of electricity. If in the future smart electricity grids will become readily available, with prices that vary with the availability of (renewable?) energy, these dynamically distribution models could prove beneficial. A study done by the MIT University and content provider AKAMAI used spot prices on the open market and load data from AKAMAI to determine what datacenter it was most cost-effective to assign the load to (Qureshi, Weber, Balakrishnan, Guttag, & Maggs, 2009). Google actually already does this in some way, but then not based on power consumption, but on cooling opportunities. In Belgium, they built a datacenter that operates without the use of additional chillers. If due to less favorable weather conditions the temperature rises too high to be able to cool without additional equipment, they can shift workloads to other datacenters. (Higginbotham, 2009)

1.2.2: *Locating near power, preferably renewable energy sources*

A very good reason to save up on power is the availability of power. There are examples where the powergrid was unable to deliver enough power to keep up with the growth in power requirements of a growing datacenter (Reams & Brown, 2010). Google has built a datacenter near a hydropower plant to assure a steady delivery of green power. Not only enough power is of importance, big datacenters are under improving attention of pressure groups to acquire power from renewable energy sources. Greenpeace for example has sought media attention to try to make Facebook run its new datacenter on renewable energy sources (Greenpeace, 2010). Because a lot of companies report on their CO_2 emissions, one of the easiest ways to reduce harmful impact from operating IT lies in the usage of green, renewable energy sources.

1.2.3: *Locating near external cooling opportunities*

Other cooling opportunities are worthwhile if they are cheap and provide an interesting Power Usage Effectiveness (PUE). PUE is a metric which is used to determine the energy efficiency of datacenter facilities. PUE is determined by dividing the amount of power entering a data center by the power used to run the computer infrastructure within it. This means PUE is a ratio, describing efficiency improvements as the quotient decreases towards 1 (Chan & More, 2009). Traditional datacenters have energy intensive (thus expensive) cooling systems. Even if you manage to reuse the heat generated by servers, the servers still have to be cooled. If you can cool servers with outside air instead of power consuming airco units, the overall efficiency is better.

HP has built a datacenter in England which uses (cold) northsea air to keep the overall temperature in the datacenter around 24 degrees Celsius. The outside wind temperature remains under 24 degrees Celsius almost the full year, only an estimated 20 hours per year extra chillers are required (Nusca, 2010).

As part of the sustainability program in an organization, they will probably set some policies to enforce certain behaviour, being behaviour from humans or computers. We identified (1.3.1) Nothing turned on overnight, (1.3.2) Automatic sleep mode, (1.3.3) Reduce energy consumption under light loads.

1.3.1*: Nothing turned on overnight*

Every computer that is running idle overnight uses power that is not used for anything of value to the primary process. Important to note is that a computer that seems idle does not always have to be idle, it can be waiting for a task, or scheduled to start a task at a specific time. An idle PC logically uses a lot more than a pc that is turned off. It would be good policy to ask users to turn their PC off if they don't require the PC to be on for useful purposes. It is possible to force this behavior to automatically shut down pc's after a certain time (for example 19:00) if they have been idle for over a certain time. It is even possible to automatically turn them back on again in the morning or during the night if your update scheme requires it. A lot of companies are cautious with this because they are afraid of data loss.

1.3.2 *Automatic sleep mode*

Most operating systems can put a system into hibernation or sleep mode. This saves the session the user is currently working on to the RAM, or even better to the hard-drive. When the session is written to RAM, a little power is required store the session on the RAM, but this is far less than keeping a PC turned on. This allows a user to return to the state the computer the computer was in before it automatically went to sleep mode. If a session is saved to hard disk, a computer can be turned off completely, and the session can still be continued more quickly than booting from a powered off PC, especially because applications that were already started can remain opened and their state will also be repaired. It is possible to force systems into this mode after a certain amount of idle time. This should not happen in a too short timeframe causing irritation for the end-users.

1.3.3 *Reduce energy consumption under light loads*

Modern computers have a lot of capacity that is not under all circumstances used. For example, if you run a program that does not require a lot of computing power like in most cases a word processor it would be a waste to have the PC running at full capacity. To prevent a computer from having excess capacity and for it to adapt to the requirements that are at that time necessary a power plan can be used. A power plan consists of a compilation of settings, both hardware and software, that aids in managing how your machine uses power. With the use of a power plan you can save energy, maximize system performance, or even create a balance between the two

(Microsoft, 2008). For laptops these plans are very common, which makes sense because it optimizes the battery life between charges. For desktops and servers that are not running intensive tasks it would make sense to scale down automatically to reduce power. New CPU technology that is not yet the standard has better automated support to do so.

We have identified 2 main responsibilities for organizations, (1.4.1) monitor emissions and (1.4.2) Creating an incentive, make IT pay for electricity usage

1.4.1:*Monitor emissions*
In a lot of organizations, it is unknown what the organizational CO_2 emissions are. An ever increasing number of organizations however realizes that sustainability reporting is becoming a mainstream part of the year reports. Organizations are increasingly pressured from governments and other stakeholders to monitor the emissions the organization creates.

1.4.2: *Creating an incentive, make IT pay for electricity usage*

If the electricity an IT organization is not distinguished from the overall electricity usage, it is unknown what the share of electricity used by IT is. Calculations have been made that depending on the primary activities of an organization's IT can take up to more than 50 percent of the total energy usage (McKeefry, 2008). If the IT department is held responsible for its own energy usage a clear incentive for saving will be made.

The second dimension, Source, can be further specified into (2.1) Assess products for environmental responsibility, (2.2) Assess suppliers for environmental responsibility (2.3) source for energy efficiency

2.1: *Assess products for environmental responsibility*

If computer equipment is ordered from the local store or ordered from large online retailers, in both cases the assembly of components is likely to be done by people near you, working under western working conditions. The components themselves are however usually made in countries that don't have too strict standards. A lot of the components are for example made in china, and recently after a streak of suicides one really big supplier, Foxconn, was forced to raise its wages (Reijerman, 2010). To understand the impact, it is important to know that Foxconn actually makes a lot of the products we use in daily life. Some of the most renowned products Foxconn makes include the iPod, the iPhone, Hewlett-Packard computers, Nintendo, Sony and Microsoft game systems. (Dean, 2007)
In order to know how environment friendly the equipment is that you're sourcing for the products should be assessed on their whole life cycle. Products should be compatible with regulations and incentives in most countries (see chapter 2.3.3). To take this to a next step look into how the product is designed for recycling and how much recycled content the product includes. Also important is the product's longevity, including upgradability and modularity. When doing contract negotiations negotiate for reduced packaging, manuals and reduced physical shipments. Ask about performance, costs and environmental trade-offs made in the design. Ask about the life cycle environmental and carbon dioxide emissions footprint of the products under

consideration. Favor vendors that have conducted life cycle assessments and can explain how they are improving the product as a consequence of conducting life cycle assessments (Mingay, 2007).

2.2: *Assess suppliers for environmental responsibility*
For small or medium organizations it is hardly possible to conduct a thorough assessment of the environmental performance of their technology or service providers. With the help of a couple of focus areas it is however possible to tell something about the actual commitment of the suppliers to the environment. Compare the sustainability report of the supplier with other sustainability reports from the same sector, looking for both level of transparency and level of detail. Furthermore it is important to look at the longevity to understand the seriousness of the efforts, and to whom it reports (stakeholders? marketing?) to understand if it is green-washing or sincere efforts, and look for an environmental assessment of the vendor's operations, products, services and supply chain. Furthermore look at if and where the technology providers are innovating in the product's life cycle. If they focus mainly on energy use when in use that is not a bad thing, but if they also innovate in material usage in products, and efficiency of their own operations that would be even better (Mingay, 2007).

2.3: *Sourcing for energy efficiency*
Power supply units (PSUs) are generally 70–75% efficient, where the remaining energy is dissipated as heat (Schuhmann, 2005). This PSU in a server or desktop machine converts the available input to voltages the machine can work with. There is a big difference in the efficiency that these power supplies operate. It would be wise to look for 80+ certified powersupplies, if power supplies have this certification this means that the power supply is at least 80% efficient at converting the input voltage to output voltage. For an "Energy Star" 4.0 certification the PSU also has to be 80+ certified. According to the certifying organization, 80plus, themselves: "80 PLUS qualified power supplies can save 16 watts on desktop PCs and 34 watts on servers during peak demand periods. Efficient power supplies directly save 85 kWh per desktop PC per year, and 300 kWh per server per year." (80plus, 2008)

Certification:	Efficiency at:		
	20% load	50% load	100% load
80 PLUS	80%	80%	80%
80 PLUS Bronze	82%	85%	82%
80 PLUS Silver	85%	88%	85%
80 PLUS Gold	87%	90%	87%

Table 1: Efficiency levels of 80% certified PSU's

Energy star certification: Energy Star is an international standard for energy efficient consumer products. It was first created as a United States government program by the Clinton Administration in 1992, but Australia, Canada, Japan, New Zealand, Taiwan and the European Union have also adopted the program. Devices carrying the Energy Star logo, such as computer products and peripherals, kitchen appliances, buildings and other products, generally use 20%–30% less energy than required by federal standards at their introduction.

New Energy Star 4.0 specifications for computers became effective on July 20, 2007. They require the use of 80 PLUS level or higher power supplies. Energy Star 5.0 became effective on July 1, 2009, and requires at least 80 plus BRONZE or higher. (Jansen, 2009) (Energystar, 2010)

The EPA released Version 1.0 of the Computer Server specifications on May 15, 2009. It covers standalone servers with one to four processor sockets. A new version of the specification covering servers with more than four processor sockets, as well as blade servers and fault-tolerant machines is expected in late 2010. (ENERGY STAR® Program Requirements for Computers Version 5.0, 2009)

The U.S. Environmental Protection Agency has also developed an Energy Star program for data centers that has been launched in June 2010. The EPA has become increasingly active in data centers. It already has an Energy Star program for x86 servers, a program for storage equipment is underway, and there are ideas to start working on an Energy Star program for uninterruptable power supplies (also called UPS) systems. (Energystar, 2010)

The third dimension is the make dimension. For clarity this dimension has been split into Make: datacenters and Make: workplaces.Within the make dimension for datacenters we specified into: (3a.1) Energy efficient use of equipment / hardware, (3a.2) Cooling in the data center, (3a.3) Power for the equipment. We further specified the energy efficiënt use of equipment into: (3a.1.1) Virtualization, (3a.1.2) Choice of platform, (3a.1.3) Consolidate storage,

3a.1.1 *Virtualization*
Virtualization enables you to use more than one instance of an operating system on a machine, even multiple different operating systems simultaneously are possible. This is a transparent process, an operating system is unaware of its virtualized status (Murugesan, 2008). Virtualizing servers in order to be green is especially useful if you have multiple servers running with a very low load. For example, one server dedicated to serving a small group of users, or a small webserver with only a few visits per day will never use its full resources (like CPU or memory). A physical server that is underutilized still uses a lot of power. Even if power saving measures have been taken, it would be more efficient to use virtualization, because of the overhead associated with running the machine. For example, every running machine has its hard disks, fans, LED's and a power supply that is not even near 100% efficient. This means that two separate machines use more power than 1 machine with a higher load. More power usage means more heat, which means more cooling, which also requires extra power.

Virtualization can also deliver other advantages, for example easy creation of testing environments, enhanced backup facilities, even load balancing options like moving a virtual machine from a physical server with a high load to another physical server with a lower load are possible.

In order to make the decision to virtualize servers it is important to keep the purpose clear in mind, it depends on the task of the machine that is replaced if virtualization is recommended. For example a DNS server or e-mail server can in theory be virtualized, but caution is in place, because having multiple virtual servers on the same physical machine does not deliver the redundancy that is probably desired. Although, in this case, you have two virtual machines that are useful as a back-up for each other in case of an operating system crash in the virtual machine, this won't help you if the physical server breaks down because of a hardware failure or power outage. (Ritschard & Herrick, 2009)

3a.1.2 *Choice of platform*

A lot of servers are built on normal relatively cheap and mainstream central processing units (CPUs) based on some variant of the x86 architecture. Most processors you would buy from AMD or Intel are modern variants of the x86 architecture. A few years back the architecture was based on the 32-bit extension, first implemented in the Intel 80386, of the earlier 16-bit Intel 8086, 80186 and 80286 processors and the common denominator for all subsequent *x86* designs. (http://en.wikipedia.org/wiki/X86) Newer types that are now considered mainstream support 64 bit extensions and other extensions meant to increase performance in specific situations. The graphics processor (GPU) on today's mainstream video cards has transformed into a powerful and flexible processor. Modern graphics architectures provide an ever increasing memory bandwidth and computational performance. High-level languages are under development for graphics hardware, enabling easier programming for these GPU architectures. GPGPU stands for "General-Purpose Computation on GPUs". There are cases known where the usage of a GPU compared to a CPU can deliver a 20 – 30 time speed improvement (folding@home, 2008) but even 100 times faster is possible in some cases (Elcomsoft, 2008). Not only is the GPU used as an alternative to the traditional x 86 processors. There are cases where for example the gameconsole "Playstation 3" is used, because of its powerful CELL processor (Betts, 2009). Also, the CELL processor itself is available for use in servers. When using for the CELL adapted software it is possible to have serious performance gains at a high power efficiency level (HPCwire, 2006). Besides the PS3/CELL there are more alternatives for the X86 architecture like the ARM, Mainframe, SPARC, Intel Itanium, IBM Power.

3a.1.3 *Consolidate storage*

It is no longer required that every server has the data it requires locally available. Solutions like Network Attached Storage (NAS) or Storage Area Networks (SAN) have often replaced the traditional Direct-attached storage (DAS). "DAS is defined as one or more spinning or streaming devices that are connected to a single server via a physical cable." (Jordan, 2002). "NAS, *Network-Attached-Storage*, is essentially a server pre-installed with a network operating system

that is fine-tuned specifically for file sharing" (Jordan, 2002) "SAN, Storage *Area Networks,* uses a centralized architecture to connect multiple servers to the same shared-storage device" (Jordan, 2002). SAN and NAS help centralizing the storage, helping eliminate multiple copies of data, reduce the administrative tasks of backup and restore and bring op utilization rates by over provisioning. Overprovisioning entails assigning more space to users than there is actually available without causing problems because not all users use 100% of the assigned capacity.

We have specified the cooling in the datacenter into: (3a.2.1) Use a hot aisle/cold aisle layout & Airflow management, (3a.2.2) Liquid cooling, (3a.2.3) Outside air, (3a.2.4) Cooling less, raise temperature

3a.2.1 *Use a hot aisle/cold aisle layout & Airflow management*
A hot aisle / cold aisle layout is a specific controlled airflow layout associated with enclosures and cabinets. Heat that is concentrated within the cabinet space enlarges the risk of overheating and damaging the equipment. (Ritschard & Herrick, 2009) To overcome heat in the cabinet cold air is placed in front of the equipment cabinets and hot exhaust air is expelled behind equipment cabinets. With the help of this layout the problem that one air intake gets the hot outtake air from other equipment. "Install filler panels in racks that are not full. Furthermore, capture the hot aisle by putting a 'roof' on it and doors on the end". This is, by far, more expensive, but also reduces long-term energy costs (Ritschard & Herrick, 2009). Figure 4 illustrates this appropriately. Not only an optimized layout helps, also clean up cables that block the airflow.
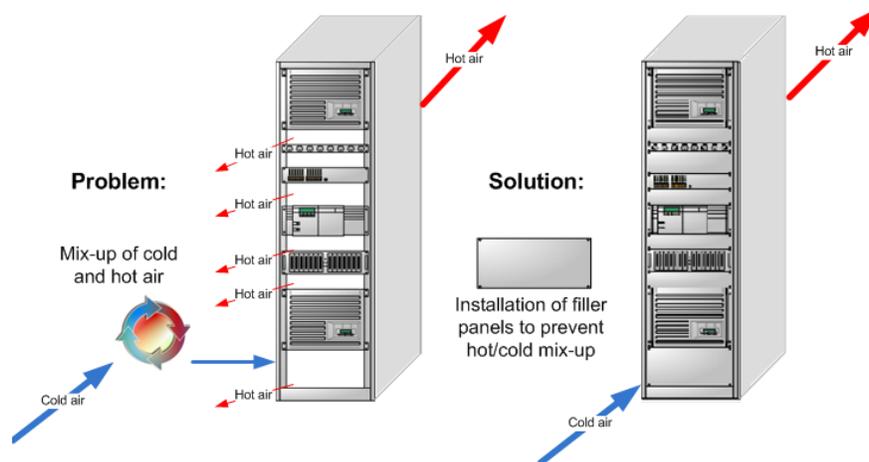

Figure 4 Installation of filler panels

3a.2.2 Liquid cooling

Liquid cooling is an efficient method of transferring concentrated heat loads compared to Air. For high-efficiency to cool the datacenter the waste heat should be transferred away from racks to a liquid loop at an as high as possible temperature. A quite common current approach would be to

use a chilled water coil integrated in some manner into the normal rack. (Greenberg, Mills, Tschudi, Rumsey, & Myatt, 2006). Besides being efficient and thus possibly cost saving liquid cooling has a larger capacity, and sometimes even enables cooling through circulation from a cooling tower thus without power consuming airco units. (Patterson & Fenwick, 2008)

3a.2.3 Outside air

HP has built a datacenter to host servers for its clients, where only 20 hours per year the outside air reaches temperatures that makes it necessary to use extra cooling facilities. The temperatures are managed to stay around 24 degrees Celsius. This datacenter is built to take advantage of the cold winds that are blown off the North Sea (Nusca, 2010). It might be clear that if it is possible to import cool air from outside the datacenter that is cooler that the air that is required to cool the datacenter this provides clear savings on air-conditioning costs. (Woods, 2010)

3a.2.4 Cooling less, raise temperature

The temperature in the datacenters is usually managed at around 20 degrees Celsius. Allowing the temperature to be a little higher can save a lot on air-conditioning costs. This should not pose a big problem, as servers can operate on a slightly higher temperature without breaking down. In traditional datacenters that have a lot of airconditioning capabilities it makes obvious sense that this saves on electricity costs, and thus saves on the CO_2 output. Raising the temperature from 20.5 celskius to 23.3 saves about 12.7% on airconditioning costs (Gibson, 2009) .

We have further specified (3a.3) Power for the equipment into: (3a.3.1) DC / Central UPS, (3a.3.2) High voltage AC, (3a.3.3) Battery in every server

3a.3.1 DC / Central UPS

Using Direct Current (DC) power straight to the server saves the conversion step a Power Supply Unit (PSU) has to make. One way to do this is to have a central UPS per rack. This central UPS also has the advantage to be able to keep your equipment up in the case of a power outage where your generators are not able to get online quickly enough. Adaptations to the now standard power supplies have to be made in order to accept Direct Current.

3a.3.2 High voltage AC

Already manufacturers are making systems that accept power at higher voltages, which cuts down on energy consumption, says Rich Lechner, vice president of energy and environment at IBM. Power enters a data centre at a high voltage, typically 480 volts, and needs to be stepped down, usually to 208 volts or lower, before it goes into the computing devices. During that process, energy is lost and heat is generated. That, in turn, drives up cooling needs and thereby increases demand for power. (Pratt, 2010)

3a.3.3 Battery in every server

Google has servers equipped with an independent 12Volt battery to keep the units running in the event of a power outage. Their savings are mainly due to the fact they don't have to convert AC to DC (power to ups-battery) and reconvert DC to AC (UPS to power), which is then converted to DC (power to PSU) as it is the case for standard UPS'. The batteries are installed where DC already exists, in the equipment. To have distributed batteries is not necessarily the most Green thought, because of the materials a battery is built from. A UPS however also has a (bigger) battery.

The second part of the third dimension, Make, is (3.b.) Workplaces. We further specified the make dimension for workplaces into: (3b.1) Virtualization for desktop, (3b.2) Platform of choice, (3b.3) Choose monitors carefully, (3b.4) Remote desktop software, (3b.5) Enabling a new way of working, (3b.6) Printing and (3b.7) Building automation.

3b.1Virtualization (desktop)
The applicability of virtualization again depends on the purpose but it alsodepends on the application. On one hand virtualization of the desktop can reduce the amount of physical machines required, for example for testing purposes, it can also be useful to reduce the amount of physical systems if combined with thin client technology. If combined with thin client technology a lot of savings are possible on hardware costs, because the applications are then processed on a server. This central processing of data also helps hardware to be used for longer periods than the standard replacement cycle (Ritschard & Herrick, 2009). However, virtualization should not be applied for all purposes, specialized applications like scientific or engineering software do not function well in a virtualized environment cycle (Ritschard & Herrick, 2009).

3b.2Platform of choice
Desktop

Desktops are still very common for office workers. The choice between platforms (like: thin client, desktop or laptop) certainly has impact on the total CO_2 output of an organization.

A study by the Fraunhofer institute indicates that – including the production and use phase – a desktop with monitor is the least environmentally responsible option (Fraunhofer Umwelt, 2008). However, it is not for all usage scenarios possible to replace the desktop. Applications where a lot of computational power is required are not worthwile to virtualize (Ritschard & Herrick, 2009). CO_2 accounted in production phase of a laptop is 117 kg.

Laptop

Laptops, as designed for mobility, and prolonged battery usage are usually more efficient with the available power. "For notebooks intended as 'desktop replacement', with a larger screen (up to

16-17") and less aggressive power management settings, the savings are still well over 50% (Energystar/Europe, 2008). Furthermore, the production of a laptop has a lower impact on the environment than a desktop, calculated to be 71 kg CO_2. Also less harmful waste is produced as a consequence of the production process. (Fraunhofer Umwelt, 2008)

Thin client

To replace a desktop PC with a thin client and the in that case necessary terminal server, there are savings possible of up to 44% on CO_2 emission, if only the accounted part of the terminal server is taken into account. In a case where thin clients are applied on a larger scale than 148 ton CO_2eq emissions over a five-year period if 75% of the workstations could be replaced with thin clients, based on a 300 total clients (Fraunhofer Umwelt, 2008).

Tablets

Recent opportunities lie in the usage of new relatively powerful tablets. Some Dutch municipalities have started to equip some of their staffmembers with ipads, and calculations have been made that these can be both environmentally friendly, and cost effective. Especially if calculations are correct they are cost effective if they save 88 pages per month, and the average city counsel member prints 1560 pages per month (Kronenburg, 2010).

3b.3 Choose monitors carefully
Older monitors based on CRT technology consume a considerable amount of power. More energy friendly are the LCD and LED monitors. When a monitor is used for 5 years a LCD monitor produces far less emission than a CRT monitor, 277kg CO_2 versus 543kg CO_2, while including production and use phase (Fraunhofer Umwelt, 2008).

3b.4 Remote desktop software
Remote desktop control software comes standard with all major operating systems, but there are also a lot of third party software solutions. This software can be utilized to administrate machines across a LAN or even an Internet connection. These software solutions provide the person on a remote location with the same view as if sitting in front of a pc. This is very helpful for locations on a distance, because it saves on traveling, thus time and carbon resources. If however the remote solution, or the operating system serving the remote solution, has crashed physical access is probably required anyway (Ritschard & Herrick, 2009).

3b.5 Enabling a new way of working
Voice over IP / IP telephone systems

Making use of Voice over IP systems makes it easier to just maintain one IP-based infrastructure to the workplaces instead of also having to maintain the old analogue telephony systems. This provides advantage in maintenance costs, but also makes dynamic workplaces more feasible. Dynamic workplaces are, along with a paperless working mindset, enablers to make teleworking a feasible option and thus enable cut downs on office space. This also enables a user working

from home to login to his IP-phone system and have the same number as he would at work. (Galitzine, 2008)

Teleconferencing

Teleconferencing is an arranged virtual meeting between parties in order to live exchange information among several persons and machines, remote from one another but linked by a telecommunications system. Teleconferencing can take on various forms, terms such as audio conferencing, telephone conferencing and phone conferencing are also sometimes used to refer to teleconferencing. The telecommunications system supports the teleconference by providing audio and sometimes video, by one or more means, such as telephone or computer. Internet telephony involves conducting a teleconference over the Internet or a Wide Area Network. One key technology in this area is Voice over Internet Protocol (VOIP). Popular software for personal use includes Skype, Google Talk, Windows Live Messenger and Yahoo Messenger.

Teleworking (Telecommuting)

Teleworking is about offering the possibilities to employees to work from remote locations (for example, flexible office or home). Some of the advantages are reduced travel related carbon footprint and reduced travel time. Teleworking increased 150% between 1997 and 2005 – a growth driven mainly by an increase in people teleworking in different places with home as a base (up from 2% to 6%)   (Banister, Newson, & Ledbury, 2007) To overcome security issues of employees wanting to access resources from their homes technological solutions like Virtual Private Networks (VPN) can be used. It is also possible to enable the employee to login to the corporate Voice over IP network from his home to have the same number at work and at his remote location. Telecommuting allows for easy savings on the transportation energy costs, and if a lot of employees work from home on a regular / known basis savings on office space are also possible. Also an added effect of telecommuting is the shift from energy usage from offices to homes. The increases in household energy use are around 11 to 25% of the energy savings on travel. This leads to the conclusion that the actual net energy saving is 11–25% less than the energy savings due to travel. (Mokhtarian & Handyllan-Salomon, 1995)

Besides energy savings, telecommuting also delivers non-negligible benefits for the employees that like the flexibility. The research done by James (2004) for the SusTel project has shown that there are positive benefits for both employees and companies. The research has linked improved recruitment, retention, higher productivity, improved work-life balance and lower absenteeism with telecommuting.

3b.6 Printing
In order for printing to be more environmentally friendly it is important to realize the paper used by printing already takes its toll of the environment. Double-sided printing should be a policy or set to be the default option. This could save in theory about half of the paper expense if users did not print double sided out of their own. Printers are often not turned off and in the case of older

printers these use a lot of power while in standby mode, new printers provide better power saving modes. A reduction in the amount of printers. New printers are based on gel toner instead of laser toners, which requires less heat to print. Another nice opportunity can be "pay per page", where the person printing has also an economic incentive to print less.

3b.7 Building automation

To further cut the energy requirements of facilities HVAC (Heating, Ventilation and Air-Conditioning) and lights sensor networks can be applied to monitor for presence. This enables to automatically keep the desired temperature, keep the air quality and lightning as required only when people are present. It has been estimated that 25 to 40 percent reductions in lighting energy use are possible by implementing an automated lighting control program, and most facilities will return on these investments in two years or less (Piper, 2004).

The fourth dimension is the dimension: (4) Return. The return dimension is further specified into: (4.1) Waste management / Recycling, (4.2) Reuse components, (4.3) Reuse heat.

4.1 Waste management / Recycling

In order to make sure the electronic waste that is produced by your organization does not end up on landfills, or in the hands of people without the required skills and without the proper equipment that extract the metals out of waste by burning it, attention has to be paid to the waste management (Guerreiro, 2010). There are cases known where towns with "recycling" activities are polluted in such a way that in blood traces abnormal high amounts of for example lead are found. E-waste is, instead of properly disposed, filling landfills or burned where lead, cadmium, mercury, chromium, polyvinyl chlorides ends up in nature, partly because poor countries don't have the right materials and safety equipment to dispose e-waste safely (CBS - 60 minutes, 2009). E-waste is one of the fastest growing waste streams (Widmer, Oswald-Krapf, Sinha-Khetriwalb, Schnellmannc, & Boeni, 2005). Although the proper handling of waste may not be beneficial, not handling your waste properly might cause more damage if word comes out your organization is responsible for a lot of toxins.

4.2 Reuse components

One can question if there are good reasons to renew the arsenal of computers in use at the speed this usually happens."By using the hardware for longer periods of time, the total environmental footprint caused by computer manufacturing and disposal can be lowered (Murugesan, 2008). Usually computer equipment is economically depreciated before it fails to function. This does not mean the equipment is useless. Especially for work that does not require much computing power this depreciation period could be higher. (Mingay, 2007)

4.3 Reuse heat

A datacenter uses a lot of electricity that is almost all turned to heat. All the generated heat must get out of the server room, but if the building that is housing the datacenter also has other uses than storing servers, like office space, savings on heating costs are a nice possibility. The main

issue here is that if it is a large datacenter it generates that much heat that even the office space does not require all the heat.

There are initiatives that reuse the heat for district heating. This way the heating is not limited to one office space, but residential areas can use the heat generated by a datacenter. (Gelens, 2009) There is also the example of an IBM datacenter nearby a pool that uses its hot air generated by the center to flow through heat exchangers to warm water that is used to keep the swimming pool at the right temperature. (Miller, 2008) Another good example is reusing the heat for greenhouses. This not only stimulates the reuse of heat, but greenhouses are usually located where a lot of space and power is available. Greenhouses are usually very well connected to the power grid making power readily available. Furthermore, a lot of greenhouses nowadays can generate power. (Keijzer, 2009)

Introducing the Maturity for IT Sustainability model: MITS

In order to describe the current state of Green IT within organizations a maturity model can be developed. "A maturity model essentially describes the development of an entity over time, where the entity can be anything of interest: a human being, an organizational function, an organization, etc" (Klimko, 2001). Batenburg and Versendaal (2008) describe that maturity "is presented by sketching a number of growth stages that depict the potential-upward development or performance of organizations during several sequential periods of time." The first concept of a staged maturity model dates from 1973 and includes a staged maturity model for IT in business functions (Nolan, 1973).

This chapter presents our Maturity for IT Sustainability (MITS) model under development, which maps all available Green IT measures from the Strategic Green Ontology (SGO) into a maturity model to guide incremental organizational improvements in IT sustainability. The MITS distinguishes the following four development stages in IT sustainability: (1) Cleaning up the waste , (2) Preventing waste, (3) Product reengineering, and (4) IT as an opportunity.

We have implemented sustainable development stages over well-known maturity stages like the Capability Maturity Model (CMM) because CMM is used to describe processes and practices. Note that the MITS is not usable from a process perspective as is, unless an extra mapping of the measures to processes is made. Although the sustainable development stages found in literature are generally aimed at environmentally sustainable development practices of entire companies, these can be adapted for IT usage. The maturity stages can, when it is in line with the sustainability strategy described earlier, provide grip to IS/IT organizations, or organizations with an IS/IT department that want a sustainable strategy for their IT department. These stages will enable a person to assess the current state of environmental IT sustainability in, and enable development of a strategy that enables for competitive advantage.

(1) Cleaning up the waste: In the first stage of sustainable development the general aim is usually to reduce the waste after the production of a product. Applying this principle to IT, this would involve reducing the CO_2 output or energy usage of creating or delivering the product. For example, consider an organization where IT is supporting the primary process, with a physical machine running an e-mail server. Optimizing the internal air flow for optimal usage, or even allowing the datacenter temperature to rise with 1 degree Celsius provides savings, meaning less CO_2 emission. The above example shows how good use of green opportunities can be made without affecting the primary process, or even changing the product/service that is delivered with IT. When relating this to the 5 steps derived from Porter & Kramer as described earlier, one can conclude that opportunities at this level are typically of the responsive CSR nature.

(2) Preventing waste: In the second stage of the model an organization realizes that in the current situation there is more room for improvement. This still happens (almost) neutrally to the primary process. Instead of "cleaning up waste", this stage tries to prevent waste during the production. For example when referring to energy usage, what does not get used does not need to be

accounted for. A possibility would be to consolidate the server running the e-mail server to a virtual machine, if it is possible to combine with other virtual servers. Opportunities at this level are of the responsive CSR nature.

(3) Product reengineering: During this stage the product or service is assessed for opportunities to be more sustainable. This entails (re)engineering the product to adapt it for easier (less energy used during) production, or to substitute harmful components with components that are less harmful for the environment. This imposes changes to products or the primary process.
An example of reengineering the product could be rewriting applications to use them on a modernized architecture or different platform.
At this level the initiatives start to be of a strategic nature.

(4) IT as an opportunity: These stages from the reviewed literature show a full commitment to sustainable development. New reengineered products might also provide opportunities for new business models. When this is seen in the context of IT organizations within companies, this is the stage where companies realize that sustainable IT entails more than reducing the negative environmental impacts that IT has, IT provides opportunities to reduce negative environmental impact on other areas. This improves the overall organizational sustainability, made possible by IT. Initiatives in this category are typically the strategic corporate responsibility initiatives.

How to apply the MITS model
If the found measures and the above described stages are combined and applied to an organization it will help grow awareness on how to address environmental and social issues, and how the IT department can become an enabler for organization wide sustainability. It remains important to realize this model is not written for a specific organization, or even a specific sector.

Start with initiatives that show immediate enhancements for the environmental sustainability (the first level, "Cleaning up the waste") without involving customers or other parties than the IT department. This is to start on a small scale, and prepare the department for changes and to give a good example.

At maturity level 2 ("Preventing waste") the direct customers of the IT department can be involved and again the quick wins are executed. At this stage the environmental impact of the measures is growing. Again this serves as preparation for later levels. As Porter & Kramer (2006) explained in their research being responsive to issues in the value chain is important, but strategic CR requests more commitment.

Maturity level 3 ("Product reengineering") is about out of the box thinking, how the current application of IT can be done in another way. At this point the customers of the IT department will notice things have changed. For example, where people requesting for a testserver used to get assigned a physical machine, they now get assigned a virtual machine. At this stage the IT department has its share in the sustainability goals set for the whole organization.

To reach maturity level 4 organizations must realize IT poses not only a threat, but it can assist parts of the organization to do certain things in another way that is more environmentally friendly, which can in turn help differentiate from competitors.

Figure 5 shows how the measures can be mapped to maturity levels for an average organization.

		Stage 1 **Cleaning up the waste**	Stage 2 **Preventing waste**	Stage 3 **Product reengineering**	Stage 4 **IT as an opportunity**
Govern / policies		Make IT pay for electricity Nothing turned on overnight	Power saving schemes Update and aggregrate	Make person responsible for G_IT init Automatic sleep mode Locate near cooling opportunities Locate near (renewable) power	Monitor emissions Automated turn off and wake Auto loadbalancing between DC's
Source		Comply to legislation	Renewable energy sources Procure energy efficient	Procure energy efficient Assess supp environment responsibility	Assess supplier environmental responsibility
Make	Datacenter	Air flow management Higher temperature	High voltace AC Hot aisle / cold aisle outside air Consolidate storage	Battery or central UPS Virtualization Liquid cooling Choice of platform Application portfolio renewal	Cloud computing
	Workplaces	Print double sided	Monitors Platform of choice	Desktop virtualization Voice over IP prints from account	Building automation Teleconferencing Teleworking Green competition / paperless
Return		Recycle	Follow up on waste management	Reuse	Track environmental info

Figure 5: The Maturity for IT Sustainability (MITS) model (under development)

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