Incorporating sustainability into information technology management

ABSTRACT
Information technology (IT) industry accounts for approximately 2% of global carbon dioxide (CO₂) emissions. Data centres use a significant amount of energy. This has become problematic during the last few years. Power intensities have been increasing over time, largely because of the increasing heat density of IT equipment. The number and usage of PCs have been rapidly increasing worldwide. By implementing IT sustainability programmes, organizations can drastically reduce the amount of energy spent, develop efficient technology products, keep e-waste out of landfills and adopt recycle and reuse programmes. Using more efficient technologies can help consume fewer resources and emit less waste. This article discusses various aspects of sustainable IT programmes and proposes sustainability metrics for IT to demonstrate a positive impact on the environment.

INTRODUCTION
Information technology (IT) industry accounts for approximately 2% of global carbon dioxide (CO₂) emissions (Gartner 2007; Marwah et al. 2009b). IT products include data centres, servers, personal computers (PCs), telecoms networks and devices and printers. About 75% of the ecological footprint...
comes from the use of IT products and 25% embodied carbon in IT products. The embodied carbon is emitted during extraction, manufacture, distribution and operation of IT products. The IT carbon emission is estimated to grow at 6% each year until 2020 (The Climate Group 2008). Current growth in energy consumption and carbon emission puts IT industry in an unsustainable condition. The IT industry needs to proactively consider life cycle analysis (LCA) of its products and innovate to reduce environmental impact.

IT organizations have started to take environmental sustainability as part of corporate social responsibility (CSR). They are showing willingness to be responsible for their environmental impacts on the society and are adopting a higher level of transparency (Caldelli & Parmigiani 2004). Hundreds of large companies have already identified themselves as ‘green’ companies and have started reporting their green initiatives according to the guidelines of the Global Reporting Initiative (GRI 2008). Recently, Newsweek (2009) published the environmental ranking of America’s 500 largest corporations consisting of technology, utilities, retail, consumer products, transportation and industrial goods sectors.

Sustainability is meant for addressing the environmental, economic and human aspects of taking care of society for the long term (Atlee 2005; Atlee and Kirchain 2006). It is ‘a characteristic of a process or state that can be maintained at a certain level indefinitely.’ The term sustainability has been defined in many different ways by different people, institutions and organizations. One widely accepted definition is from the Brundtland Report, ‘sustainable development is the development that meets the needs of present without compromising the ability of future generations to meet their own needs’ (World Commission of Environment and Development 1987). The concept of sustainable development represents a reaction to the degradation caused by economic growth, unfettered by a consideration of environmental and ecological issues (Lombardi and Basden 1997). The ‘economic growth’ of many ‘unnecessary’ products has contributed to environmental pollution.

Today, we are confronted with growing evidence that contemporary, modern society is not sustainable (Ikerd 2010). Industrialization is not sustainable given its excessive use of natural resources and causing of imbalance in ecology. Industrial systems are inherently extractive, exploitative and ultimately dependent on finite stocks of non-renewable resources (Ikerd 2010). IT sector is heavily dependent on energy, the most of which comes from non-renewable resources such as fossil fuel. IT can improve environmental sustainability and contribute to a greener planet in a number of ways. Heavily used IT equipment includes data centres, servers, PCs and printers. Many companies have drastically reduced power consumption by adopting efficient technologies, efficient processors and virtualization of equipment.

By analysing IT asset data such as PCs, servers and printers, an organization can reduce the amount of unnecessary equipment and other assets it purchases or owns. Analysing different means of packaging and shipping manufactured goods can result in less packing material, which transforms into less waste to dispose of at the back end. Smaller packaging also means less fuel used in transportation. An IT operation consumes large quantities of electricity to run and cool the servers and equipment and maintain the IT facility. Many organizations are working to remove redundant data, minimize and consolidate the number of redundant databases and eliminate outdated and unused systems and servers. All of these initiatives contribute directly to an organization’s bottom line and help achieve environmental sustainability.
Since the seventeenth century industrial revolution, we, the industrial world, have become dependent on industrial output in maintaining our daily lives. Our use of resources and discharge of wastes proceed at a rate which overshoots the carrying capacity of the Earth (Bastianoni et al. 2001). A comprehensive systems approach is essential for effective analytical decision-making with regard to global sustainability, because industrial, social and ecological systems are closely linked (Fiksel 2006; Lombardi and Basden 1997; Martin 2005). For IT product design, LCA is needed to identify the energy used by each stage of a product. In addition, the amount of energy used by each component needs to be identified. Thermodynamic analysis can be conducted to determine exergy and entropy calculation in each part of a product or each phase of a process or operation. We need to find various ways to reduce footprint and come up with metrics for IT sustainability.

We need to explore the possibilities as to how we can prudently use these resources with exceeding limits and which cause burdens on earth’s carrying capacity. Economist Herman Daly has suggested three simple rules to help define the sustainable limits to material and energy throughput (Meadows et al. 2004): (i) for renewable materials, ‘the sustainable rate of use cannot be greater than the rate of regeneration’. For example, fish, soil and water; (ii) for non-renewable materials, ‘the sustainable rate of use cannot be greater than the rate a renewable resource can be substituted’. For example, fossil fuel and mineral and (iii) for pollutants, ‘the sustainable rate of emission cannot be greater than the rate at which that pollutant can be recycled, absorbed, or rendered harmless in its sink.’ For example, sewage in lake and carbon in the sea. Any activity that causes a renewable resources stock to fall, pollution sink to rise and non-renewable resources stock to fall without a renewable replacement insight cannot be sustained (Meadows et al. 2004). This is true for IT products as well because they use fossil fuel-based energy/electricity.

The major driving force for transformation is the public concern about the environmental impact of the present fossil fuel-based energy system. A mixture of measures including energy efficiency, a switch to natural gas, major investments in low carbon and renewable energy technologies and underground storage of carbon are elements of such new strategies (Vellinga 2000). We need to satisfy our needs by judiciously using renewable resources, recycling wastes and end-of-life products for beneficial uses, and reversing environmental degradation in some areas and minimizing environmental impacts in others (Sikdar 2007).

THE LITERATURE – A CURSORY SURVEY

Sustainability, as a broad area, has been a research topic for more than three decades. The research (Blevis 2007; Lems et al. 2003; Meadows et al. 2004; Norde 1997) is mostly related to ecological, economic and social aspects of sustainability. IT is an important area from the environmental sustainability standpoint as it consumes significant amount of material and energy resources.

Over the last three decades, awareness of sustainability has increased significantly in government, industry and the general public. Policymakers worldwide have sought to incorporate sustainability considerations into urban and industrial development (Fiksel 2006). In the IT sector, sustainability could be achieved by better managing the IT products and accessories to use less energy, and hence emit less carbon. IT companies can manage their retired computers and other electronic products by handing over to others for reuse.
instead of holding them in storage. They should find environment-friendly way to recycle PCs, cell phones and other electronics.

To address environmental concerns, IT companies can adopt different measures to save natural resources. Under the product stewardship programme, 28% (by weight) of all plastic resins IBM® procured through its corporate contracts contained recycled plastic content. The net recycled plastic content weight represented 8.1% of IBM’s total purchases (recycled and virgin plastics). IBM’s product end-of-life management operations worldwide processed 53,670 metric tons of end-of-life products and product waste and sent only 1.59% of the total to landfills, versus IBM’s goal to minimize its product landfill use rate to no more than 3%. Dell® is accelerating its programmes to reduce hazardous substances (MATRIX) in its computers, and its new OptiPlex desktops are 50% more energy-efficient than similar system manufactured in 2005 (Kurp 2008). HP’s new desktop computer exceeds US Energy Star 4.0 standards having an expected life of at least five years, and 90% of its materials are recyclable (Kurp 2008). Intel® Xeon® processor 5500 series can dramatically advance the efficiency of IT infrastructure and provide unmatched business capabilities (Intel White Paper 2009). While acquiring printers, monitors and PCs, organizations can adopt sustainability measures by purchasing only those products which meet the ‘energy star’ criteria. Many companies use notebooks to increase energy efficiency. For instance, Intel Corporation (Wellsandt and Snyder 2009) has been utilizing 80% notebook PCs which consume less power compared to desktops. Zero-client technology is the latest trend in reduced footprint computing.

Advances towards sustainability will require system-specific metrics to assess both current performance and the impact of operational, technological or regulatory changes on that performance (Atlee 2005; Atlee and Kirchain 2006). Currently, there are few operational metrics to practically assess progress towards sustainability (Atlee 2005). In this article, an attempt will be made in developing and evaluating system-specific performance metrics for IT sustainability. We show that there are opportunities to use reliable performance indicators towards achieving sustainability in development, manufacture and use of IT products.

ENVIRONMENTAL SUSTAINABILITY OF IT

IT sustainability is ‘the study and practice of using computing resources efficiently’, using more efficient technologies to consume fewer resources and emit less waste. Since the late twentieth century, IT emerged as a new area of concern from the environmental sustainability standpoint given IT’s dependency of electrical power as well as natural resources.

IT sector’s emissions are expected to increase. In 2007, the total footprint of the IT sector – including PCs and peripherals, telecoms networks and devices and data centres – was 830 MtCO2e, about 2% of the estimated total emissions from human activity released that year. This Table looks set to grow at 6% each year until 2020 (The Climate Group 2008). The carbon generated from materials and manufacture is about one-quarter of the overall IT footprint, the rest coming from its use. In 2002, the PC and monitors’ combined carbon footprint was 200 MtCO2e and this is expected to triple by 2020 to 600 MtCO2e – a growth rate of 5% per year. Table 1 shows projected growth rate of IT footprint for PCs and monitors, data centres and telecom devices. The direct carbon footprint
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Table 1: Current and future growth of carbon footprint in IT (derived from the Climate Group Report).

<table>
<thead>
<tr>
<th>ICT Carbon Footprint</th>
<th>Footprint in 2002</th>
<th>Footprint in 2020</th>
<th>Projected Growth Rate</th>
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<tbody>
<tr>
<td>PC and monitors</td>
<td>200 MtCO2e</td>
<td>600 MtCO2e</td>
<td>5% per annum</td>
</tr>
<tr>
<td>Data Centers</td>
<td>76 MtCO2e</td>
<td>260 MtCO2e</td>
<td>7% per annum</td>
</tr>
<tr>
<td>Telecoms infrastructure &amp; devices</td>
<td>150 MtCO2e</td>
<td>350 MtCO2e</td>
<td>5% per annum</td>
</tr>
</tbody>
</table>

of the IT sector is dominated by electricity consumption, so an obvious way to reduce emissions is to use as much electricity as possible from renewable sources such as solar power.

In the United States, data centres have used 1.5% of electric power in 2006 (Kurp 2008). This consumption rate will most probably increase every year. Furthermore, IT as a whole is responsible for 2% of global carbon emissions. Thus, even a small percentage savings in the energy consumption of data centres will have a huge economic and environmental impact (Kurp 2008). We can improve IT efficiency using new energy-efficient equipment, investing in energy management software, adopting environment-friendly designs for data centres and new measures such as new generation microprocessors for computer servers to deal with data centres’ energy consumption (Murugesan 2008).

Material aspects of IT sustainability

Material intensity
Using more material to manufacture products causes destruction of natural resources which has a direct impact on the environment. On the contrary, material selection (Murugesan 2008) is also important from the standpoint of less energy consumption in PCs and data centre equipments/ servers. For example, use of aluminium (Bash et al. 2008), in IT products, causes excessive consumption of energy for PCs and data centres. Thermodynamic analysis could be conducted to quantify materials required to produce and process (Letteri et al. 2009) and associated energy consumption. For PC and data centre equipment manufacture, LCA could be used in the daily operation (Kurp 2008) of IT products manufacturing.

Design of PCs and data centre equipments
Environmental sustainability could be achieved through well-thought-out design and manufacturing of IT products and equipments. It is important that IT organizations come up with the design of environment-friendly material parts, products and equipments. They need to quantify how much energy is consumed in each stage of computer and server manufacturing. The design and manufacturing process of PCs and data centres could be done through exergy analysis (Murugesan 2008). Lifetime exergy consumption of IT products needs to be measured as IT products and equipments use significant amounts of resources. In PCs power management technology could be enabled to keep track of energy used per hour of operation. There are some other approaches such as thin-client computers used to minimize the use of resources in computer manufacture and power consumption.
Beyond invention and disposal, renewal and reuse
IT products and equipments have rapid depreciation. They face early retirement from service due to frequent obsolescence. Hence, longevity of IT products needs to be increased and from that perspective sustainability should be a central focus for design (Blevis 2007).

Process optimization rate of IT equipments
IT organizations need to continuously work on process optimization. This helps in achieving less material consumption and thereby less energy use. In data centres, new energy efficient equipment needs to be used. In data centres, the whole process needs to be optimized to remove inefficiency or redundancy. Server virtualization has been found to be an effective strategy to bring efficiency in IT. Many IT organizations replace their relatively older computers with new technologically improved and energy-efficient computer hardware.

Users may choose to employ thin-client computers which draw about a fifth of the power of a desktop PC. There could also be breakthrough technologies that would transform how PCs use energy. Examples include solid-state hard drives, which could reduce energy consumption by up to 50% (The Climate Group 2008).

Renew, reuse and refurbish of PCs
Given PCs and other IT products have short lifespans, IT organizations can do a good job by making efforts to renew, reuse and refurbish PCs to maintain environmental sustainability. Consumers discard old PC monitors and other equipment every two to three years after purchase which ends up in landfills (Murugesan 2008). When purchasing IT products and equipments, criteria, need to be set regarding easily reassemble and easily upgradable products. This will allow less natural resources use and to save the environment.

Dematerialization through IT
IT organizations can contribute in saving natural resources as well as emitting less carbon through various ways. By virtue of IT the organizations can take advantage of video conferencing instead of air travel. Teleworking could be used instead of commuting to work every day. Printing on paper could be replaced with e-billing. IT organizations need to monitor how much resources are being saved by these efforts.

Energy aspects of IT sustainability
Energy consumption has a major impact on climate change because of the burning of fossil fuel generates CO₂ (GRI 2008). The IT organization needs to measure the overall carbon footprint they command. This will help them to come up with a plan to minimize that. They need to keep an account of the total energy being used. Effective measures need to be taken to reduce energy consumption to help achieve environmental sustainability.

Non-/Renewable energy use
Non-renewable energy such as fossil fuel is the main source of energy for the last few decades. The use of fossil fuel to generate energy is the root cause of much carbon emission. Because IT consumes a huge amount of energy, the IT organizations need to capture metrics as to how much non-renewable energy is being used and how much renewable used. All efforts should be
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made to reduce dependency on non-renewable energy. The IT organizations should switch to renewable energy-based sources such as solar power, wind, hydrogen, etc. They need to strive for using equipments that use fewer resources.

Percentage of improvement in energy efficiency

IT organizations need to establish a CO₂ usage baseline and address consumption and waste (Beckert 2009). Improvement of energy efficiency in IT has been a great driver for the last few years. IT organizations have been making numerous efforts to gain energy efficiency and bring down carbon emission. They need to determine the amount of energy being used and how much efficiency gain is being achieved.

Many companies including Intel Corporation have found server refresh as an effective strategy to achieve significant energy savings. The new servers in the market with Intel® Xeon® 5500 series processors are referred to as the most powerful processors to achieve data centre efficiency (Intel Corporation 2009). Intel’s microprocessors’ dramatic improvement is considered as a major breakthrough in reducing power consumption of data centres. The server refresh strategy is taken as the number one driver of IT’s carbon footprint reduction. The server refresh strategy is used to increase efficiency while reducing cost and energy consumption. Accelerating server refresh takes advantage of performance and power efficiency improvements.

The data centre virtualization

Virtualization technology is another way to reduce the energy consumption of data centres. To efficiently use underutilized capacity of local servers, data centre virtualization is used, which uses idle servers at remote data centres. Data centre virtualization has helped to maximize the use of existing server capacity (Beckert et al. 2009). Data centre virtualization is treated as an essential element of broader data centre efficiency programme because eliminating site dependencies enables IT organizations to consolidate data centres and boost utilization. This enables the same performance with less power consumption.

IT organizations need to develop a comprehensive approach to metering power usage to identify measurable efficiency improvements and to continuously track power usage effectiveness. This is the key metric of data centre energy efficiency. Energy consumption needs to be monitored and volume needs to be decreased. IT organization might also shift their direction towards the use of renewable energy. They need to use and advocate the use of solar power. One other thing that IT organization needs to do is to commit to producing, sell, buy and use the most energy efficient IT equipment. They need to do research and make an effort for the expansion of alternate energy sources such as solar and wind geothermal. To scale back power consumption of PCs, they might adopt a policy of using ‘energy star’ products and equipment. For example, Intel® 45 nm processors have enabled lower idle power and higher performance levels. These processors exceed Energy Star and other regulatory requirements for idle power consumption in desktop PCs, and lowers electricity and cooling costs for servers (Allarey et al. 2008).

Enabling power management features

Without sacrificing performance, IT organizations can program computers to automatically power down to an energy-saving state when they are not using
them. The US Environmental Protection Agency (EPA) estimated that providing computers with a sleep mode reduces their energy use by 60–70\% (Murugesan 2008). Microsoft’s Windows 7 operating systems have enabled this feature.

THE THERMODYNAMIC LIFE CYCLE ANALYSIS

The life cycle is the dominant principle in eco- and sustainable design (Sherwin 2004) and has been applied most effectively in manufacturing. Using LCA in designing a product considers the larger context including materials extraction, production, transportation, use and disposal and attempts to minimize environmental impacts across this entire life cycle (Sherwin 2004). Thermodynamic LCA is an ‘input-side’ approach, relying mainly on the data about consumption of natural resources expressed in terms of available energy (exergy) (Fiksel 2006). Thus, it is particularly useful in the early stages of technology innovation.

Thermodynamic potential is a measure of a material or system’s ability to perform work. In thermodynamic analysis, two important things are calculated. One is the exergy which is a measure of available energy that is available to perform certain work. The other is the entropy which is a measure of the unavailability of energy (exergy loss). Thermodynamic analysis has been helpful in comparing and improving the energy efficiency of all kinds of technological processes (Lems et al. 2003; Prek 2004; Reuter 2008). The energy efficiency is evaluated in terms of how much power is consumed during an operation. The sustainability of energy use for information processing depends on the lifetime exergy or available energy consumption of the equipment used (Hannemann et al. 2008). Exergy analysis helps in locating weak spots in a process. It improves our insight and allows us to design processes systematically (Streich 1995).

All matter and energy in the universe are subject to the Laws of Thermodynamics (Hanson 1997). Thermodynamic analysis studies the transformation of energy and materials through processes (Dewulf and Langenhove 2005). The second law of thermodynamics states that whenever a work goes through some industrial process and whenever energy is used, available usable energy declines compared to input energy. The second law of thermodynamics states that all processes generate entropy which means that available output exergy is always less than input exergy due to internal and external loss exergy. The exergy concept, sometimes called availability, is the thermodynamic tool that expresses the quality of energy. Exergy is a very useful basis for describing the efficiency of IT products.

The irreversibility of each natural and technological process and the inherent degradation of the quality of energy are quantified by the loss of exergy (Dewulf and Langenhove 2005). In Figure 1, we see that exergy ‘Inputs’ are much greater but after it has gone through some industrial process the availability of exergy goes down. Exergy loss (entropy) happens in terms of external and internal exergy losses. Internal exergy loss occurs due to irreversibility. The external exergy loss happens in terms of by-products and effluents. The available exergy is a part of energy that can be converted to work of a rotating shaft; one can think of exergy as an equivalent of electricity (Patzek 2008). Entropy is that part of energy that must be dissipated as heat and cannot be converted to work of a rotating shaft. Entropy was defined by the formula (Patzek 2004):

$$\Delta S = \frac{\delta Q}{T}$$
where $\Delta S$ is the entropy increment, $\delta Q$ is the quantity of heat transferred from a hotter to a colder body and $T$ is the absolute temperature at which the transfer is made.

IT products and equipment are heavily dependent on energy. For IT products the thermodynamic LCA should be conducted in identifying the inefficiency. Data centres use a significant amount of energy to supply three key components: IT equipment, cooling and power delivery. These energy needs can be better understood by examining the electric power needed for typical data centre equipment and the energy required to remove heat from the data centre. Data centre equipment generally exhibits high power intensities with all of the electric power converted to heat. Moreover, power intensities have been increasing over time, largely because of the increasing heat density of data-processing equipment (EPA 2007).

The lifetime exergy consumption of each energy-consuming item in the data centre needs to be explored. Scenarios involving various servers and cooling loads could be examined to simulate the variation in exergy consumption between different operating conditions (Hannemann et al. 2008). Although the operational and cooling power consumption account for the majority of the lifetime exergy consumption, material extraction and manufacturing exergy costs are still significant. Additionally, the use of different materials can have a significant effect on exergy consumption and should be considered as an important design parameter (Hannemann et al. 2008). Therefore, in each stage of product life cycle, thermodynamic LCA needs to be conducted and exergy costs in terms of internal and external exergy loss need to be addressed.

**RECYCLING IN IT**

IT products and equipments have a relatively short lifespan. Establishing effective recycling and reuse systems can contribute significantly in increasing material and resource efficiency. They also provides insight into the degree to which the organization has designed products and packages capable of being
recycled or reused (GRI 2008). The current trend is to replace PC every three to four years. This causes millions of computers to become obsolete within a few years. One of the decommission strategies is recycling. Recycling is ‘the reprocessing of old materials into new products, with the aims of preventing the waste’.

Recycling is one tool of many that can be used in cradle-to-cradle (Werner 2008). Cradle-to-cradle is a framework used to design ‘production techniques that are not just efficient but are essentially waste free’. Recycling and cleaner production can dramatically reduce, but never eliminate, the waste and pollution per unit of consumption (Meadows et al. 2004). The goal for recycling IT products is to reduce environmental impact and to lessen demands on landfill space (Atlee 2005). A sustainable human society must conserve, recycle and reuse materials and energy; it is to slow, rather than accelerate, the process of entropy (energy loss) (Ikerd 2010).

The recycling and recovery of a component depends on how the product is designed, what type of materials are used in it and if different parts can be separated. In general, recycling effort encompasses all stages of a product’s life cycle. Sustainable systems are ‘circular’ (outputs become inputs) – all linear physical systems must eventually end (Hanson 1997). In nature, there is no waste, because one creature’s wastes become another’s nutrients (Fiksel 2006). To maintain environmental sustainability, IT products need to be designed and manufactured in a well-planned way so waste of natural resources can be avoided and most of the material could be recovered. In the post-consumer phase, a hierarchy of measures including product remanufacturing, module or parts reuse and materials recycling is recommended (Lambert et al. 2004).

IT organizations need to keep track of recycling rates of their IT products and equipments. They need to calculate how much recycled materials are used in those products, equipments and devices. When purchasing IT products and equipments, it is important that purchase is done from the manufacturers who offer products with components that could be unassembled easily and are more recyclable. Design should take into consideration environment-friendly computers made of recyclable materials. The laws need to be enacted to have manufactures take responsibility to collect and recycle IT products.

**IT SUSTAINABILITY AND CONSUMER HABITS**

Proper use of IT products is another major area that needs to be considered to achieve environmental sustainability in IT. PCs are no longer a luxury. In developed countries they are available in every household. In developing countries PCs have gradually become common household items. But IT companies can play a major role in influencing the individual users as to how to use computers in efficient ways to enable energy savings. Disposal of computers in an environment-friendly way is another area that needs to be role modelled by IT organizations.

Although it is evident that IT products and equipments consume huge amount of energy, it is a right approach to strive for technological innovation, increased operational efficiency in IT products. But it is also true that efficiency in production and innovation of technology are not sufficient to address carbon emission of IT sector unless we take a holistic approach. For that we need to address this at product consumption level as well. Savings of energy through operational efficiency and environment-friendly technology might be
counteracted by an increase in more consumption of IT products. Consumer habit is an important aspect to consider for IT sustainability.

‘Does technological innovation to improve the efficiency of energy-using products and systems lead to lower energy consumption and hence reduced environmental impacts? The answer given by economists since the mid-nineteenth century is, “no”’ (Herring and Roy 2007). This is true when efficiency brings down product price and which leads consumer buy more. More consumption offsets the energy reduction achieved through technological innovation. Our consumption pattern needs to be revised. This is no small challenge to industrial societies, where consumption has traditionally been an end in itself (Hart 1997). Yet companies are often in the best position to help customers reduce consumption. They can provide helpful tips of their products towards monitoring the consumption of energy per hour of use and the consequent CO₂ emission to the environment. To achieve complete sustainability, a complete ‘sustainable consumption’ policy should not only include ecological but also social parameters (Zaccai 2008). It would not be effective to minimize energy consumption at production level, while allowing it unrestrained at the consumption level. Education has been given a crucial role when shifting from unsustainable to sustainable consumption patterns (Krajnc et al. 2008).

A social movement is needed to encourage private and public offices and individual citizens for judicious use of IT products. Any unnecessary use causes energy waste, environmental pollution, depletion of natural resources and emission of CO₂. To achieve savings in electricity consumption, the utility companies should provide helpful tips on how to save energy in using computers, printers and lots of other electronics equipments for office and household use. Consumers and businesses cannot manage what they cannot measure (The Climate Group 2008). The manufactures in IT industry need to provide a solution that enables users to ‘see’ their energy and emissions in real time. The utility companies can print helpful tips in the billing statements. The IT companies may construct some indicators to express the resource utilization and emission spread during the usage of products. This will allow users to become conscious of the consequence of overuse of the products. Laws need to be enacted to compel the manufactures to collect and recycle IT products.

**SUSTAINABILITY METRICS FOR IT**

The processes of developing more appropriate measures requires both a more critical assessment of new and existing metrics, and a period of trial and error (Atlee 2005). Objective here is to characterize what makes effective metrics (for sustainability), and to assess operational metrics (Atlee and Kirchain 2006) for IT products. The criteria for developing metrics are usefulness, robustness and feasibility (Atlee 2005). Advances towards IT sustainability will require system specific metrics to assess both current performance and the impact of operational, technological or regulatory changes on that performance. There is a need for systematic ways to describe system functioning and quantitative methods to assess system performance (Dresner 2002).

In Table 2, we have come up with an IT sustainability metric which is compliant with GRI format. The aspects in the environment indicator set are structured to reflect the inputs, outputs and modes of impact an organization has on the environment. Materials and energy represent the two standard types of inputs used by most organizations. These inputs result in outputs of
<table>
<thead>
<tr>
<th>Indicator Aspects</th>
<th>Performance Indicators</th>
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<tbody>
<tr>
<td><strong>Materials</strong></td>
<td></td>
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<tr>
<td>Percentage of materials used that are recycled input materials [GRI]</td>
<td></td>
</tr>
<tr>
<td>Material intensity in IT products and equipments [Murugesan, 2008]</td>
<td></td>
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<tr>
<td>Design of PCs and Data Centers [Rauch &amp; Newman, 2009; Manwah et al., 2009]</td>
<td></td>
</tr>
<tr>
<td>Process Optimization Rate of IT equipments [Gartner, 2009; Murugesan, 2008]</td>
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<tr>
<td>Recycling Rate [Atlee, 2005; Wellsandt &amp; Snyder, 2009; Rauch &amp; Newman, 2009]</td>
<td></td>
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<tr>
<td>Rate of hazardous and toxic materials used [Kurp, 2008; Murugesan, 2008]</td>
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<tr>
<td>Renew, reuse, and refurbish of PCs [Kurp, 2008; Blevis, 2007; Murugesan, 2008]</td>
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<tr>
<td>Denmaterialization drive through IT [Wellsandt &amp; Snyder, 2009]</td>
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<tr>
<td>Percentage of products sold and their packaging materials reclaimed</td>
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<tr>
<td><strong>Energy</strong></td>
<td></td>
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<tr>
<td>Percentage of overall carbon footprint that IT controls [Rauch &amp; Newman, 2009]</td>
<td></td>
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<tr>
<td>Percentage of Renewable energy consumption [Climate Group Report, 2008]</td>
<td></td>
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<tr>
<td>Percentage of Non-Renewable energy consumption</td>
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<tr>
<td>Percentage of savings through energy efficiency [Alarey et al., 2008; Kurp, 2008; Lettieri et al., 2009; Bash, et al., 2008; Manwah, 2009]</td>
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<td>Percentage of savings due to process improvement</td>
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<tr>
<td><strong>E-Waste</strong></td>
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<tr>
<td>Environmental impacts of transporting products and materials [GRI, 2008]</td>
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<tr>
<td>Percentage of hazardous material exported [GRI, 2008]</td>
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<tr>
<td>Percentage of reduction in carbon intensity [Climate Group Report, 2008]</td>
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<tr>
<td>Percentage reduction in carbon emission from travelling [Climate Group Report, 2008]</td>
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<tr>
<td>Percentage of transported waste shipped internationally [GRI, 2008]</td>
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<tr>
<td>Percentage toxic material discarded [Wellsandt &amp; Snyder, 2009; Widmer et al., 2005; Mocigemba, 2006]</td>
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Table 2: Sustainability metrics for IT.

environmental significance, which are captured under the aspects of emissions, effluents and waste.

Materials used by volume provide information about an IT organization’s initiative to reduce material intensity and conserved natural resources. Material volume and intensity consists of materials used in different stages of product life cycle including extraction, manufacturing process and final products. Another aspect of materials is how much renewable and non-renewable materials are used. This information has various implications including cost reduction, increased profitability and savings of natural resources. This also means less waste disposal. How much material savings achieved due to introduction of LCA – from material extraction to manufacture, to disposal process? This can help reduce the cost of finished products and equipments. How much material savings achieved due to LCA, thermodynamic analysis and material selection in extraction, manufacturing, use and disposal processes? How much environmental savings achieved by using renewable materials. What is the ratio of renewable and non-renewable material consumption? This indicates IT organization’s contribution to conservation of natural resources (GRI 2008).
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In designing products materials selection is important. Materials differ from energy efficiency standpoint. This is evident from life cycle exergy analysis of materials. Use of excessive amount of aluminium in PCs and data centres will cause excessive amount of energy or exergy consumption. How much material savings achieve due to process redesign? How much materials being used are recycled. This indicates an IT organization’s ability to use recycled materials and reduce the demand for natural resources. Substituting recycled materials can help IT organization to lower overall cost of operation (GRI 2008). The rate of hazardous and toxic materials needs to be quantified. This needs to be asked while purchasing products from external sources or suppliers. This will show how much effort is exerted to get reduced hazardous substance from products.

The quantity of hazardous materials in IT products needs to be calculated given short lifespan of computers. At the end of their life time, these products in many cases end up in landfills. These hazardous equipments also travel from industrialized countries to under developed countries. To avoid harm to human being and environmental pollution, IT organizations need to choose products containing less hazardous materials. By keeping track of manufacture, use and disposal of hazardous materials, IT organization can make significant contribution in keeping environment clean and emit less pollution. IT products have short lifespan. However, renew, reuse or refurbish initiative will help save natural resources and reduce disposal. Although purchasing IT products, it is important to know how easy it is to reassemble or if the product is upgradeable. How many new purchases could be avoided or delayed due to implementation of programmes such as renew, reuse, refurbish and upgrade.

What percentage of energy savings achieved through energy efficiency measures? How much increase of efficiency achieved in PCs and data centres? Example includes the use of high-efficiency geothermal heat exchanges for cooling and heating, real-time tracking of carbon emissions at data centres, deployment of next generation microprocessors and adoption of virtualization strategies for PCs and servers. How much savings achieved through process redesign, retrofitting of equipment, and exergy analysis in the LCA? All these initiatives indicate IT organization’s proactive efforts to improve energy efficiency through technological improvements of processes (GRI 2008).

How much environmental impact is caused due to transporting products and materials (The Climate Group 2008; GRI 2008) related to IT operation? What percentage of hazardous material is exported (GRI 2008)? This indicates the ability of management. What percentage of reduction achieved in carbon emission from business travelling (The Climate Group 2008), such as air travelling? How much travel avoided due to video conferencing units at IT sites. This helps IT organization achieve cost savings. The IT organizations need to track all sorts of energy consumption to improve overall life cycle performance of products and services (GRI 2008).

What percentage of transported waste shipped internationally (GRI 2008) and what percentage of toxic material discarded (Mocigemba 2006; Wellsandt and Snyder 2009; Widmer et al. 2005)? This helps achieve compliance with regulation set by national and international agencies and governments. E-waste is an emerging issue, driven by the rapidly increasing quantities of complex end-of-life IT equipments. The global level of production, consumption and recycling induces large flow of both toxic and valuable substances (Widmer et al. 2005). IT organizations need to measure e-waste it is causing and steps taken to overcome this issue.
CONCLUSION

Sustainability programmes can provide business value in many ways. For IT, the most important sustainability lever includes emission reductions given its heavy dependency on energy which mostly comes from non-renewable source. The other IT sustainability levers include efficient use of fuel, judicious use of natural resources, materials safety and waste reduction that can keep our environment clean and human lives save. An organization’s move towards sustainability should be guided by strategic analysis, effective programme management, performance measurement and executive-level support (GRI 2008).

The main focus of this article was to suggest new ways to use sustainability programmes to bring efficiency in IT and reduce carbon footprint. We have concentrated on the problem of IT products and equipments sustainability in terms of selecting energy efficient materials, judicious use of raw materials, inputs and natural resources. We also emphasized the use of energy efficient materials in products. We suggested different techniques and strategies to bring energy efficiency in PCs and data centres. We proposed to take advantage of life cycle exergy analysis of PCs and data centre products, equipments and processes to isolate inefficient areas which destroy exergy.

We proposed a comprehensive sustainability metrics for IT. Our proposed metrics took into consideration all aspects of IT products and equipments from LCA standpoint. We pointed out measures that start from extraction of raw materials to the disposal of final products after use. We pointed out measures to increase energy efficiency in PCs and data centres in processes and products and equipments. Our proposed approaches would allow IT companies to bring efficiency in energy use and to keep track of the rate of renewable and non-renewable energy use. This will allow IT organizations to reduce environmental footprint.

Having said all these sustainability measures, the ultimate IT sustainability relies on its switching from fossil fuel-based energy source to renewable energy source. The use of solar energy can ultimately make IT sustainable. Sustainability is possible only because the Earth, as a ‘open system’, is capable of capturing and storing sufficient amounts of ‘useful’ solar energy to offset the declining ‘usefulness’ associated with the inevitable tendency towards entropy (Ikerd 2010).

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