Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 29 (2015) 432 – 437

www.elsevier.com/locate/procedia

The 22nd CIRP conference on Life Cycle Engineering

Life Cycle Assessment of CRT, LCD and LED Monitors

Vikrant Bhakar, Aashray Agur, A. K. Digalwar, Kuldip Singh Sangwan*

[a]*Birla Institute of Technology and Science, Pilani, INDIA - 333031*

* Corresponding author. Tel.: +91-1596-515730; fax: +91-1596-244183. *E-mail address: kss@pilani.bits-pilani.ac.in*

Abstract

The increasing consumption patterns in emerging economies like India and China with half the world population has increased the environmental concerns. E-waste in these countries is rapidly increasing and monitor is one of the major contributors to it. The paper aims at assessing the life cycle environmental impact of Cathode Ray Tube (CRT), Liquid Crystal Display (LCD) and Light Emitting Diode (LED) monitors. Life Cycle Assessment (LCA) of three widely used monitors has been performed based on the international standards of ISO 14040 series. The LCA was constructed using Umberto software version 5.6 and expressed with both CML (Centrum voor Milieuwetenschappen) 2001, mid-point assessment method and Impact 2002+, end point assessment method. This study is expected to guide policy makers in government to improve e-waste management strategies and also it will create awareness among the user. The monitor manufacturers may leverage the study to improve the environmental impact of these products. Sensitivity analysis for the use phase has been performed to confirm the robustness of results.

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering

Keywords: life cycle; environmental impact assessment; end-of-life; e-waste management

1. Introduction

In recent times, the access to personal computers (PCs) has increased many folds. One of the major components of these PCs is monitor. The monitor technology has rapidly changed in last two decades, from cathode ray tube to liquid crystal display, plasma display, light emitting diode, organic light emitting diode, etc. Moreover, the increasing penetration of PCs in emerging economies like India and China with half the population of the world will increase the number of monitors required worldwide. For example, in terms of sheer numbers, the Indian PC market is higher than that of many of the developed countries [1]). Dwivedy and Mittal [2]) has predicted that the PC penetration in India could overtake that of US (highest PC penetration) by 2046, while the number of obsolete computer inventory in India will be two times that of US by 2022.

Monitors consume a significant amount (15 to 35%) of energy in PC system [3]. According to EE Times [4], it is estimated that by 2014-15 market share of LED monitors will increase to 80% and LCD market share will come down to less than 20%. It is estimated that out of 260 million display units expected in market by 2014, major contribution will be of LED only. Major benefit associated with LED display is its lower power consumption during use phase.

Electronic Industries Association of India (ELCINA) has estimated that commercial sector accounts for 80% of total market penetration of computer and IT hardware in India. The association report on consumer behavior highlights that at corporate/business level only 6% of the organizations were found to be disposing off their computers in environment friendly manner [5]. A monitor generates many environmental impacts throughout its life cycle. The manufacturing of a monitor is a complex process, involving many hazardous materials as well as precious metals. The use phase of a monitor consumes considerable amount of electricity, and End-of-Life (EoL) phase can seriously affect human health, if not properly disposed off. For example, liquid crystal mixture of LCD and LED monitors contains benzene, cyano-group, F, Cl, etc., which are potentially harmful to human health and environment [6]. Similarly, plastic housing and frames contain brominated flame retardants such as Poly Brominated Di-

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering
doi:10.1016/j.procir.2015.02.003

phenyl Ethers (PBDE) and Poly Brominated Bi-phenyls (PBB), which are harmful to brain, kidneys, nervous system, liver, endocrine and reproductive systems [6].

Complex components used in monitors such as PWB (Printed Wiring Board) have a large variety of precious metals such as gold, silver and hazardous materials like lead (Pb) [7]. A recent review has revealed that there is high concentration of Pb, PBDEs, PCDD (Polychlorinated di-benzo dioxins) and PBDD (poly brominated di-benzo-p-dioxins) in air, bottom ash, dust, soil, water and sediments in WEEE recycling areas of the developing countries as compared to developed nations [8]. The ancillary materials like nitrogen tri-fluoride (NF3), which is used during the manufacturing process of LCDs to clean the vacuum chambers, can cause a lot of environmental impact, as it is a greenhouse gas with a global warming potential (GWP) 17,000 times more potent than carbon dioxide (CO2) [9].

The increasing awareness of environmental protection and the possible negative effects due to the activities at every stage of a product's life cycle, i.e. production, distribution, usage, and disposal, have led to the creation of plethora of concepts, strategies, approaches, tools, etc. to assess and understand the environmental impacts of products throughout their lifecycle [10]. Life Cycle Assessment (LCA) of products throughout various phases is one such approach used to find the environmental impact of products during pre-manufacturing, manufacturing, use, and disposal. This paper aims at assessing the environmental impact of high growth market segment of PC monitors. The paper also compares the most prevalent CRT (Cathode Ray Tube) monitors in developing countries, widely used LCD (Liquid Crystal Display) monitors in developed countries and fast emerging LED (Light Emitting Diode) monitors.

LCA is an investigative instrument that incorporates all the environmental impacts of a product, process and human activities from raw material extraction, production, use phase and waste management [11]. LCA is the internationally standardized environmental assessment method [12] with a methodological framework for estimating and assessing the environmental impacts attributable to the life cycle of a product, such as climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, resource depletion, water use, land use, noise, etc. [13]. Few LCA studies have been conducted to assess the environmental impacts of CRT and LCD monitors at different geographical locations [9] [14] [15] [16]. Such studies are not available for emerging economies which have poor e-waste management and poor quality of energy mix. This paper provides LCA of CRT, LCD and LED monitors as well provides a comparative assessment of these monitors in an Indian context on different parameters. Further, the results are expressed using CML 2001 and Impact 2002+ methodologies. Sensitivity analysis has also been performed to check the robustness of the results. This paper is expected to help the industry in general and Indian industry in particular to take better decisions during purchase and replacement of monitors. It will also guide the government policy makers to develop better policies for e-waste management.

2. Materials and methods

A typical desktop PC is an assembly of three main components, i.e. monitor, CPU and key board. With technological innovation in the recent past, there is a drastic improvement in each of these components especially in the monitors. CRT monitor is the oldest and heaviest and requires maximum power amongst the three monitors. LCD monitor uses different technology and is sleeker compared to CRT. It uses Cold Cathode Fluorescent Lamp (CCFL) as its light source in the backlight unit and has liquid crystals sandwiched between the glasses of its screen. LED monitor in principle is an LCD monitor as it has the same display screen, but uses light emitting diode instead of CCFL as light source in the backlight unit [17]. The environmental performance of the three monitors has been done by conducting an LCA study based on the international standards of the ISO 14040 series [13][18] [19].

2.1. Goals and Scope

2.1.1. Objectives of the Study

The objective of the study is to assess and compare quantitatively the environmental impacts of CRT, LCD and LED monitors on different parameters covering various aspects of nature, i.e. human health, ecosystem quality, climate change, resource depletion, etc., and thereby to find the monitor which causes the least environmental burden.

2.1.2. System Boundaries

The scope of the present study is a traditional LCA from cradle to grave, i.e. from the extraction of the various resources used in the production of these monitors to the final disposal at the end of life. The production data of various parts of the monitor was obtained from the Eco-invent database 2.2. However, due to lack of availability of data with respect to transportation between various distribution channels in India because of diversified and complex transportation system, transportation has not been included in the system boundary. Indian electricity mix has been created based on the data provided in Table 1.

2.1.3. Functional Unit

The functional unit of the study is taken to be a standard monitor with a diagonal viewing area of 15 inches, working 240 days a year for 6 year in which five hour normal operation, two hour sleep mode and one hour standby mode. The CRT monitor closest to that diagonal viewing area is a 17 inches CRT monitor which has diagonal viewing area of 15.9 inches [20]. The other possible design parameters for monitors are brightness, resolution, weight and power consumption [16]. Kim and Kara [16] have pointed out the limitations of functional unit as the products are sold and bought as a whole unit and not based on the functional unit.