LIFE CYCLE ENERGY ANALYSIS OF PCS – ENVIRONMENTAL CONSEQUENCES OF LIFETIME EXTENSION THROUGH REUSE

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Abstract - Due to the short innovation cycles of PCs they are usually replaced by a new generation product years before they reach the end of physical lifetime. Therefore a reuse of PCs is desirable to improve the (eco-)efficiency. A project in Berlin and Hamburg, Germany, supports the regional networking of PC recyclers, refurbishers, and dealers to establish the infrastructure for improved PC reuse. Research at the Technical University of Berlin assesses the environmental aspects of PC reuse, having the complete life cycle in mind: A new set of life cycle data was created to compare reuse of a four-year-old PC with disposing the old one and buying a new model. This comparison tackles several crucial aspects of LCA, including definition of the functional unit for different product generations and comparability, and rebound effects as low cost reuse PCs give access to ICT to even more people.

The life cycle evaluation focuses on energy as the major environmental aspect of ICT. The differing energy consumption of different PC generations for manufacturing as well as use has a significant effect on the energy balance. The energy burden of electronics manufacturing is comparatively high due to the complex high-tech processes needed. On the other hand energy consumption of the use phase of frequently used electronic devices, such as PCs for office use, normally exceeds the energy burden of manufacturing. Thus, the use patterns of PCs dominate the environmental effects of reuse strategies.

1. INTRODUCTION

The life cycle of today's information technology is characterised by short innovation cycles concerning hardware as well as software. This technology progress is accompanied by a society, where state-of-the-art equipment is attractive for the consumer, even if most of the new features of every new product generation are not really needed by the average user. The result is, that the life cycle of information technology is much shorter than the potential technological life time. To achieve a longer life time for IT equipment the project ReUse "Local networks for reuse of electronic devices" [1] in Berlin and Hamburg, Germany, is currently establishing a network of recyclers, retailers, and repair workshops, which aims at improved logistics, quality assurance, and marketing of used computers and components. The ReUse project has

- a social dimension – as social enterprises are involved, refurbishment is labor intensive work, and cheaper PCs become available for people, who could not afford a PC of their own before -,
- an economic dimension – as new fields of business for small domestic companies are opened -, and
- an ecological dimension – as PC ReUse is assumed to contribute to a sustainable use of high tech equipment.

To figure out the environment-related benefits, and maybe obstacles, of PC reuse the Technical University of Berlin, Research Center of Microperipheric Technologies, analysed the energy consumption of PCs for the whole life cycle [2]. There are some studies cited in literature, assessing the environmental impacts of personal computers, but all of them are outdated - see the above mentioned technological progress -, therefore a completely new calculation of life cycle aspects was undertaken.

2. GOAL AND SCOPE

There is no reliable data on average life time of personal computers. Literature data varies between 2 and nearly 6 years [3, 4]. It is assumed, that in average four years is a common time line for PC replacement.

The system to be analysed are 1999 and 2003 PCs with all internal components (mainboard, processor, sound card, graphics card, hard disk drive, floppy drive, CD-ROM drive, power supply, cables, and housing), no peripheral devices and input units (no monitor, no mouse, no keyboard, no printer etc.). The 1999 PC

(Pentium II, 350 MHz) now is a typical candidate for reuse, competing with a new state-of-the-art PC (Pentium 4, 1,8 GHz).
The life cycle energy analysis focuses on the following questions:

- What are the impacts of the different life cycle phases?
- Which of these impacts can be reduced through reuse?
- What is the environmental benefit of reuse?
- Which components should be reused with priority to achieve the highest energy savings possible – do some components have a significantly heavier "energy rucksack" than others?

Energy was decided to be analysed as the main environmental parameter of the environmental assessment, as the energy consumption of manufacturing – see earlier studies – was assumed to be very significant, as global supply chains seem to result in an important contribution of transports, and as PCs during the use phase are consuming energy. The primary energy consumption is analysed for all life cycle phases: raw material extraction, components manufacturing, assembly, transportation, use, depending on the scenario refurbishment and reuse, and disposal.
Data sources for the manufacturing processes are not the older studies on PCs but recent scientific papers, environmental reports, roadmaps, the KEA database of the German Federal Environment Agency [5] to fill gaps concerning raw materials, energy supply, and transportation, disassembly of representative 1999 and 2003 PCs and the know-how of BeCAP in the field of electronics interconnection and packaging technologies.
The reuse scenarios to be compared are:

I. User A buys a PC in 1999 and uses it for 4 years, then gets rid of the PC via a recycler or a ReUse PC retailer, and buys a new one (using it for 4 years). User B buys the 4-year-old ReUse-PC in 2003 and uses it another 2 years before disposal (material recycling / energy recovery).

II. User A buys a PC in 1999 and uses it for 4 years, then buys a new one in 2003, but stores the 1999 PC another 2 years for "emergency" reasons, before he disposes the old PC in 2005 (material recycling / energy recovery). User B needs a PC in 2003 and buys a new one (using it for 4 years).

III. User A buys a PC in 1999 and uses it for 4 years, then buys a new one in 2003, but stores the 1999 PC another 2 years for "emergency" reasons, before he disposes the old PC in 2005 (material recycling / energy recovery). User B needs a PC in 2003, but can't afford a new one or doesn't buy a new one for other reasons. For, at least, the following 2 years he is without a PC of his own.

These scenarios imply methodological problems for figuring out the environmental benefits of reuse: The functionality of a 4-year-old PC is different than that of a new one. On the other hand it's a question of individual preferences, if advanced animated PC games are of the same usefulness as "simple" office programmes – which run also on older PCs without major problems. The case study presented here compares as functional unit "one year use of PC", not making a difference, how old the PC is.
While applying this functional unit it has to be kept in mind, that using a 4-year-old PC for another two years is only sensible, if the PC still fits to the individual software applications to be run. This will be the case especially for standard office applications. A reuse PC will not meet the required functionality, if the PC is intended for advanced graphics programs,
Boundary conditions for the use phase are of great importance for the overall inventory results. The range of "real" PC users includes the professional power-user as well as the user, who uses the PC only for typing letters now and then. To find a representative use scenario is hardly possible. This case study refers to the average use patterns as analysed by Fraunhofer ISI [6], see tab. 1.

	use-hours per PC annually		
	home use	office use	weighted (65,8% home use, 34,2% office use)
user interaction	398	1.705	845
stand-by	1.333	495	1.046
off (but connected to power supply)	4.920	5.248	5.032

Table 1 – Use scenario (according to Fraunhofer ISI)

This use scenario is related with some uncertainties, especially as 5 to 6 year old

reuse PCs might be used less frequent than up-to-date PCs, due to the limited functionality.
Power consumption during the different use modes was measured for different PC configurations.
Energy consumption for repair and spare parts is not included in this study: Spare parts for PCs also have to be reused parts, as compatibility with different PC generations is limited. Therefore, no new spare parts will be manufactured for reuse, but the infrastructure for supplying used components has to be established.

3. LIFE CYCLE ENERGY INVENTORY RESULTS

The main results of the life cycle inventory are:

- Primary energy consumption of manufacturing a PC in 1999 is about 485 kWh (including final assembly). Transportation of major manufacturing supplies and the PC components – which are mostly produced in East and South East Asia – to the European market is another 51 kWh.
- For a PC manufactured in 2003 primary energy consumption for manufacturing (incl. transportation) is about 10% less.
- Comparison of primary energy consumption for manufacturing with component prices of 1999 (see fig. 1) shows significant deviations: market price is of limited value as an indicator for energy consumption in the field of high-tech equipment. Other price factors are much more relevant.

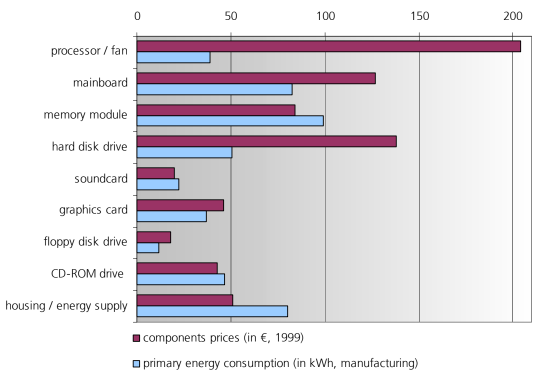

Figure 1 – 1999 PC inventory results (primary energy for manufacturing) compared to market prices

- Main environmentally relevant components of a PC are memory modules (due to IC area), mainboard (complexity) and housing / energy supply unit (amount of material).
- Energy consumption measurements for the use phase showed, that the power consumption of an average 2003 PC is about one-third higher than that of a 1999 PC, despite the improvement of power saving features of new PCs – with which the average PC user is not familiar! See fig. 2 for the development of the energy consumption of Intel processors.

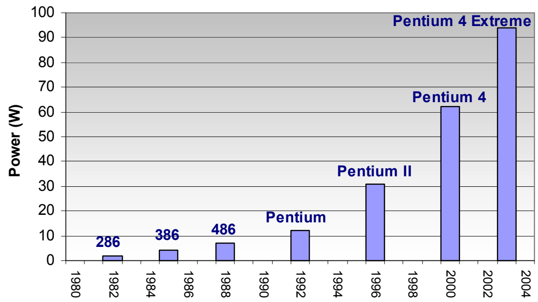

Figure 2 – Energy consumption of Intel processors [7, 8]

- Proper material recycling of metals and PVC and energy recovery from other plastic parts corresponds to a recovery of about 72 kWh primary energy (replacement of primary material).
- If the PC is disposed off contrary to legal requirements with household waste in a waste incineration plant at least the ferro magnetic parts are separated and recycled, energy from incineration is recovered as well. The primary energy credit of waste incineration and recycling of iron of a PC is 32 kWh.

The results of the three scenarios for reuse of PCs are shown in fig. 3: The reuse scenario I compared to scenario II reduces primary energy consumption absolutely as well as “per year PC use” by 11%, meaning 65 kWh per year.
Scenario III (no PC for user B at all) – of course – turns out to be of less energy consumption than scenario I (reuse PC for user B). This comparison is not “fair”, as the function for user B is not the same. The comparison via the functional unit “1 year of PC use” results in a balance where scenario III sums up to 40 kWh more per use-year, meaning a higher efficiency for reuse than using no PC at all.

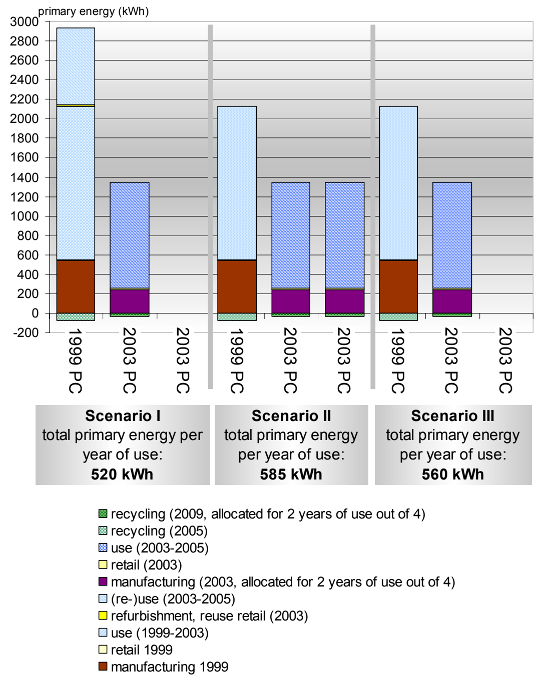

Figure 3 – Comparison of reuse scenarios

4. INTERPRETATION

The hierarchy of proper end-of life management: reuse – first priority, recovery – second priority, proper disposal – third priority, is also valid for high-tech trash. But the environmental "gap" between reuse and recovery is much larger than for other products: Only about 13 % of the energy used for manufacturing and transportation of the PC can be recovered (replacement of primary material) with state of the art recycling facilities.

For a 4-year old PC at average use modes the use phase represents about 77% of the life cycle energy consumption. Thus, the reuse of PCs is an environmental benefit anyway, as older PCs use less energy. Enhanced reuse might result in a rebound effect, as more potential users get access to cheaper PCs (one of the targets of the ReUse project!), resulting in more energy consumption through information technology equipment. As shown by this study the eco-efficiency of PC use (energy burden per use year) is increased by reuse, even if there is the mentioned rebound effect.

Retail and refurbishment do not contribute significantly to the overall energy consumption: The network infrastructure to be established by the ReUse project does not result in notable adverse effects concerning an increase in transportation.

About two million used PCs changed hands in Germany in 2002 [9]. Assuming that each of these reuse PCs replaced a new PC for one year, the primary energy saved sums up to about 470 GWh. Furthermore, there is an estimated "hidden reserve" of about 16 million PCs with an age of 3 to 6 years in Germany. An enormous potential to be activated for reuse – and the environment.

5. REFERENCES

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