

# Environmental impacts of computers in Belgium

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## **Abstract:**

In the framework of a study focussing on four product categories (namely housing, packaging, cars and computers), we modeled their annual impacts in terms of GHG emissions, raw material use and waste production over their life cycle for the years 1990 – 2010. The results showed that though the impacts of computers in households are small, they are increasing at an amazing pace (+ 150% GHG emissions in 2010 compared to 1990). Moreover, about half of the impacts occur in the production phase, due to the manufacturing of chips.

Different strategies could be envisaged in order to decrease these impacts, in the framework of a product policy. Concerning computers, 5 strategies were identified: stabilising the demand, substituting products, increasing the lifespan of computers, improving consumers' behavior and increasing recycling. The strategy that rises as the most important one is increasing the lifespan of computers, which of course decreases the impacts due to manufacturing. Targeting the demand could also lead to significant improvement.

In a last step, key stakeholders were consulted in order to gain insight on which practical measures could be taken in Belgium. Increasing the lifespan of computers, which appeared as the top option, still has a negative image in the industry, while there are already some initiatives of repairing for reuse in Belgium by the social economy. Targeting the demand is foreseen as extremely difficult by all stakeholders, in particular due to the association between computer ownership and social status. Increasing services is seen as the best possibility.

## **Introduction**

Attention is shifting more towards examining the potential of policies oriented at improving products and consumption patterns. This, because the sector-based, mostly 'process'-oriented environmental policies seem insufficient to reach the objectives of sustainable development. The perspective of "Integrated" in Integrated Product Policy (IPP) is the consideration of the entire product's life cycle chain and the consideration of multiple environmental problems to avoid adverse effects and shifting to other impact types.

Climate change, resources use and waste management are major challenges for policy makers and society in general. These three environmental issues constitute the core issues of the project "Integrating climate, waste and resource policies through a product policy" that started in 2002 and ended in 2004. This project was carried out within the scientific support plan for a sustainable development policy financed by the Belgian Science Policy.

After a first step aimed at the identification of key products for a product policy that would intend to reduce all three impacts simultaneously, the second step of the project studied in detail four product categories (cars, household packaging, housing and computers & paper), with the view to evaluating theoretical potentials of reduction of greenhouse gas emissions, energy use, waste production and material resource use. The last phase of the project aimed at contributing to establish a framework for the evaluation of product policy measures by stakeholders.

For the study of computers, we covered both computers in households and computers in federal administrations (as an example of an office activity). In this paper, we present the results for computers in households only, since the methodology and scope of these two parts were very different.

# Methodology

## *Determination of theoretical impact reduction potentials*

### **Elaboration of an analytical tool**

The implementation of product policy requires an appropriate approach to take into account both the different life cycle stages of products with their own environmental impacts, and the different strategies with their ability to tackle one or several life cycle stages. In the framework of this study, we have developed and used an analytical tool that aims at linking product life cycle stages with the emissions, emission reduction potentials and relevant policies and measures. It summarises how different improvement strategies of products can decrease their greenhouse gases emissions, waste production and resource use at different life cycle stages, thus making computers more efficient during their production and use. It resulted in a series of strategies that can have an impact on one or more life cycle stage; for each of these strategies, independent parameters are varied in order to reflect the potential effect of targeted policies and measures on the product characteristics.

For computers, the strategies envisaged were as follows:

Strategy 1 : Changes in final demand for the considered function: This strategy aims at changing the demand of consumers for a particular. It would, of course, influence all life cycle stages, but is not often envisaged in environmental programmes, as it influences consumption and therefore production of goods and is often seen as damaging to the economy and the quality of life.

Strategy 2 : Substitution by products fulfilling the same function: The final function can be fulfilled by different products. The design of the product (shape, material composition) can influence its life cycle impacts. For those products for which the impacts from the use phase are important, the shift from lower to higher energy efficiency or from higher to lower carbon-content fuel can also contribute to reducing the life cycle impacts. In the case of computers, we considered desktop PC with CRT and LCD screens, as well as laptops. Shifting from CRT to LCD , or from desktop to laptop, are two possibilities to fulfil this strategy.

Strategy 3 : Product reuse: Product reuse allows doubling (or more) the product's use phase, thus delaying the time when it will become a final waste. Therefore it mainly influences the waste phase and the production phase (because less new products are consumed), but also the use phase of products if their impacts vary over the time. Product reuse is mostly not considered in actual climate policies, but more in waste policies.

Strategy 5 : Rational use of the product: Properly using a product has a significant influence on its impacts during the use phase and can also extend the product life span. It is only partially considered in the current environmental policies, mainly through information and education measures. However, information is increasingly considered as insufficient to change consumers' behaviours [1]. For example, enabling power management is more likely to be successful if this is a compulsory setting on the equipment than if users are informed and encouraged to enable it. Measures envisaged in this strategy should thus focus also on technology, and not rely on users to voluntarily change their behaviour.

Strategy 7 : Increasing end-of-life products recycling: The increase of product recycling has a mostly beneficial influence on energy used/generated in the waste phase, but also on the material production and product manufacturing through the use of recycled materials or parts. In general, recycled materials need less energy for transformation. Product recycling is not envisaged as such in climate policies, but is mostly implemented through waste policies.

These strategies are product-oriented and do not target the production phase of computers (except the design phase). The improvement of the production phase was included in the business as usual scenario. Scenarios 4 and 6 (namely decreasing the product lifespan and change of composition of

the product) were not relevant in the framework of the study of computers. Another strategy had to be left out, though interesting: the decrease of transportation distances. Indeed, in the case of computers, parts are manufactured world-wide and assembled somewhere else, leading to probably important impacts in terms of fuel consumption from transportation. However this production and assembly network is so large and unknown that we could not envisage to quantify this strategy.

## **Impacts from product consumption**

A product-oriented policy would potentially aim at curbing not only impacts from products bought each year, but also impacts from products already used in the country (existing stock).

This means that both the existing stock of products and the products put on the market had to be considered in the study, especially in the development of scenarios on impacts from products, including impacts produced in Belgium but also impacts produced abroad.

As the study aimed at evaluating to what extent a product policy would contribute to the simultaneous fulfilment of the three objectives to reduce GHG emissions, waste and pressure on raw materials, impacts and impact reductions have been calculated in such a way as to fit with the following environmental objectives:

- regarding greenhouse gas emissions, the emission reduction targets agreed in the Kyoto Protocol are expressed as a percentage reduction of the average annual national emissions over the period 2008-2012 compared to the 1990 level.
- regarding waste, several types of objectives are defined in the regional waste policy documents, based on per capita annual emission ceiling and minimum recycling or reuse rates in a year.

As a result, for GHG emissions and for waste, annual emissions need to be estimated and especially "domestic" emissions.

Regarding material resources, there is no quantified objective.

Based on this approach, we calculated the three impacts for each phase:

- GHG emissions, in kg CO<sub>2</sub> equivalent
- raw material use. This impact category indicator is related to extraction of scarce minerals and fossil fuels. The Abiotic (= non-organic) Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels based on the remaining reserves and rate of extraction. It is based on using the equation,  $\text{Production}/(\text{Ultimate Reserve})^2$  and comparing this to the result for Antimony (Sb), which is used as the reference case. The reference unit for abiotic depletion is therefore kg Sb equivalent.
- waste, in kg of final waste, i.e. waste after treatment of the disposed product, thus going to landfill.

## **Calculation of annual impacts and scenarios of impacts from products**

For all four product groups studied in the project, we have developed a common methodology for the construction of alternative scenarios. The development of this methodology has been guided by two main concerns, which are to:

- reflect the annual environmental impacts from existing and new products used in Belgium from 1990 through 2010, with a clear distinction between impacts from the disposal phase of existing products, the use phase of existing products and the production phase of new products;
- quantify the individual impacts from each general improvement strategy as well as the impacts from the combination of all these general improvement strategies.

It starts with the building of a "business as usual" scenario (BAU) that reflects an evolutionary case where the current policies do not change in the future. The BAU scenario is based on the different data sets and on several assumptions regarding future trends. Alternative scenarios were then built by changing key parameters, following each of the strategies mentioned above.

## ***Stakeholder consultation on possible policies and measures***

Once the theoretical improvement potentials were determined, we envisioned how a product policy could help— at least partly — to achieve them. In order to identify measures, the expertise of stakeholders was required. Indeed, existing policies and measures in Belgium are not evaluated after

completion (ex-post evaluation) nor beforehand (ex ante evaluation). This gives us very few knowledge on the consequences of these measures.

We reviewed a series of consultation methods based on the following pragmatic criteria:

- Usability for all stakeholders
- Equity between stakeholders
- Amount of time required from stakeholders
- Possibility to express their views
- Quantitative exploitability of the results

We also evaluated cost and total time requirement for the research team.

Following the evaluation of existing methods, we chose to develop a method based on the Delphi principles [2], though not aiming at reaching consensus but rather at mapping opinions. This approach is sometimes referred to as “policy Delphi”[3].

Using quantitative notation ranges allows the determination of mean values for each question, as well as the statistical distribution. The Delphi method has been used for a long time. and allows structured answers and removes traditional bias occurring in interactive settings. Consequently, it is a good method to obtain stakeholders’ views while obtaining quantitative inputs to the model.

## **First consultation round**

A Delphi questionnaire was supplied to the stakeholders willing to cooperate that asked them to evaluate possible measures on a series of criteria:

- Technical feasibility: is technology / knowledge adequately available to implement this measure?
- Political feasibility: is there political willingness (or no political impediments at least) to set up, implement and monitor this measure?
- Effectiveness: can this measure result in a substantial reduction of at least one environmental impact (GHG emissions, resource use, waste production)?
- Acceptance by the stakeholder: would the measure be well accepted by the stakeholder?
- Market acceptance: will the affected market react positively to this measure?
- Cost for industry: will this measure substantially increase the costs in the industry concerned?
- Cost for policy: will this measure require the allocation of a substantial amount of money from the policy level for its implementation and monitoring?
- Cost for users: will this measure substantially increase the total cost of ownership (purchase price + run price) for the user?

The questionnaires were filled in through the Internet. In both rounds, we had to be very careful about the phrasing of questions and of measures. Stakeholders had the opportunity to enter new measures, as well as to rephrase the measures. We also differentiated the criteria to evaluate depending on the stakeholder in order to require less time from them.

## **Findings from round one : reorientation of round two**

We had several findings from the first round on the general methodology for this consultation.

First, although we limited the number of criteria and the number of measures to limit the time requirement from stakeholders, we had several negative reactions to this approach. Indeed, most stakeholders would have preferred to have all measures and all objectives, and select themselves the ones for which they feel they have enough expertise.

Second, the number of criteria was found to be too large to enable an easy assessment; moreover, some criteria were found either to be redundant or to have too broad a definition that would have required to split them up into other criteria. For the second round, we thus reduced the criteria to the following ones: acceptance by users (user perception and user costs); acceptance by industry (costs for industry and social costs), and efficiency.

Last, but not least, we found that the comments given by each stakeholder were more useful than the actual figures of evaluation of the different criteria in order to evaluate measures. However, the results altogether did not enable a common ground required to carry out the identification of priority measures.

Based on these findings, we decided to reorient the second round to deepen the comments from all stakeholders, with the aim to present the variety of opinions of the different stakeholders on the subject of product-oriented policies and measures.

## **Hypothesis for the modeling of computers**

For household computers, the distinction was made between laptops, desktops with CRT monitors and desktops with LCD monitors. The data sources and main hypotheses used for these different products follow.

### **BAU data**

#### *Sales and market shares*

We have few data on market shares of these different products. However, we can estimate for 2001 that laptops market share is ca. 20%, desktop with CRT screens, 65% and desktop with LCD screens 15%. These assumptions were used in the DSM study by Fraunhofer Institute [4]. In 2005 we had data from GfK on market shares of laptops [5] (46% in 2005); although we would tend to think that they are more likely to be sold to professional consumers. The rapid decrease of prices encourages the buying of laptops (but probably not always as a replacement of a desktop) and LCD screens. We assumed that after 2005, the sales of computers in Belgium will continue to increase (after the stabilisation of sales for 2003 – 2004), as it seems to be the case already for 2005.

It is very difficult to get reliable data on computer stock in households before that date. Actually, computers were only integrated in the INS annual survey on household consumption in 1995. For that year, the stock of computer is 1,28 million units. The share of the different products is not known, but it is not likely that laptops were often used by households in 1995, and LCD screens for computers were not widespread either. Therefore it will be assumed that in 1995, desktops with CRT screens accounted for 100% of the sales. The stock of computers in 1990 is unknown ; we assumed that the ownership rate was at best 20% (thus 785 722 units).

#### *Production phase*

For the composition data, we based our calculations on EPA [6] and Handy and Harman Electronic Materials Corp [7].

Data on impacts from production of materials were extracted from SIMAPRO. However, for computers, the production and assembly stages of chips are of high relevance [8], we thus used data provided by E. Williams.

#### *Use phase*

Knowing the power draw of computers is more difficult than it seems. Indeed, on central units, the wattage found in the technical specifications represents the maximum power draw, but by no means the average power draw. The maximum power is reached when all electricity consuming parts of the central units (CPU, hard disk, fan, drivers, etc) run at the same time, which is almost never the case. Therefore, it is necessary to measure the average power draw in use. Variations in power draw between different models also complicates developing an average number for the installed base. It is also more difficult to predict the future power consumption, even if it is assumed that due to higher computing speed and the increasing number of peripherals (CD writer, , etc), this average consumption will increase slightly. The growth in graphic card power draw also contributes, to a large extent, to this increase of average power draw..

For displays, the task is easier since technical specifications mention an average power consumption while in use, although these specifications may not be precise (e.g. depending on the contrast, colour level of the screen etc). In the future, due to the increased size of screens, the energy consumption is likely to increase slightly. Although CRT-based monitors' active mode power draw tends to increase moderately as screen size grows, the active mode power draw of LCD monitors increases rapidly with increased screen size. Eichhammer et al [4] estimated some figures from 2000 onwards that we used for our modelling and extrapolated back to 1990. This source of data was also used to derive values on the on and stand-by hours.

### *Disposal phase*

For 2000, OVAM (the competent body for waste in the Flemish region) reported a selective recovery rate of 95 % in 2001. In this value the computers sent abroad are also included (39%). These computers are sent abroad mainly for charity purposes, but may also contain illegal electronic waste. They will be taken into account as other end of life computers afterwards, but it should be noted that the vast majority of these computers, after a possible second use in developing countries, are likely to end up in landfills under very bad conditions.

### **Scenario assumptions**

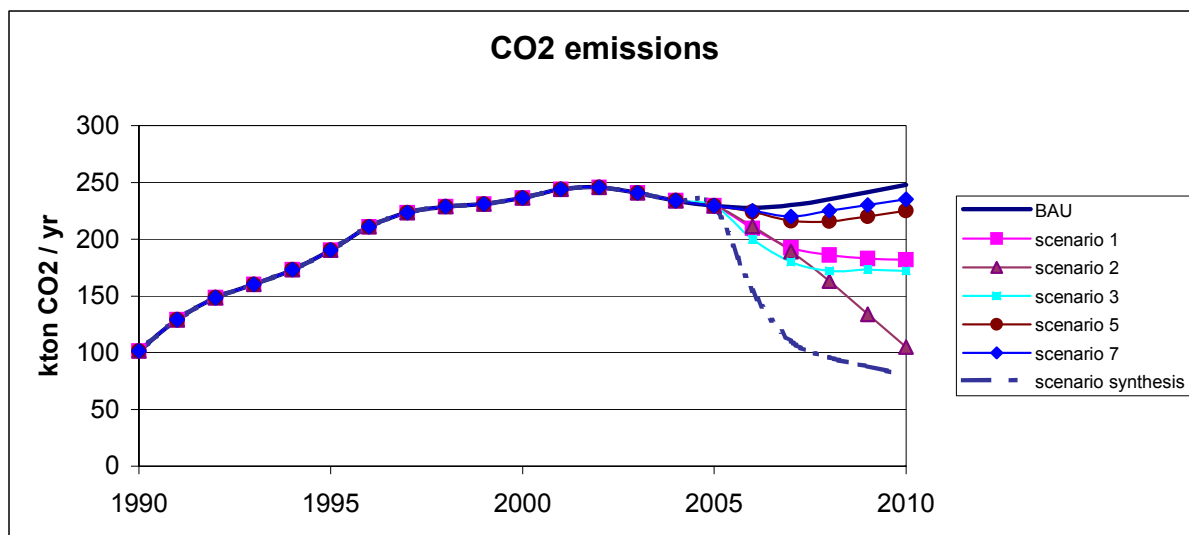
- Scenario 1 : **change in final demand** for the function: In this scenario, we assume that the penetration rate of computers in households remain constant after 2005.
- Scenario 2 **substitution of products fulfilling the same demand**: In this scenario, we assume an increased market share of LCD screens (to 35% in 2010) and laptops (to 65% in 2010) and a decrease of CRT screens down to 0% in 2010.
- Scenario 3 **product reuse**: Computers can be re-used easily as long as they meet the needs of the customer and as long as they are not too damaged when they are disposed of. Indeed, most computers are replaced because they are outdated, not because they are not working. In these conditions, they can fulfil a second use. We assumed a second life span of the same length as the first one, and these computers are assumed to replace new ones (this is optimistic). Scenario 5 **rational use of the product**: In the BAU scenario, both the time of usage and the time in standby mode are increasing. For this scenario we assumed that they remain constant after 2005, thus 370 hours in on-mode, 12250 hours in stand-by mode.
- Scenario 7 **increasing end-of-life recycling**: We assume 100% selective collection rate and 100% recycling for all materials after 2005.
- Scenario synthesis : this scenario combines the different assumptions made for each scenario.

### **Results of modeling**

In this section, we present the results of the life cycle modelling of computers including monitors in households for the 3 impacts (GHG emissions, raw material use, and waste production) for the period 1990 – 2010.

#### **Greenhouse gas emissions**

Greenhouse gas emissions mainly cover CO<sub>2</sub> emissions due to energy use during the whole life cycle. Although semi-conductor manufacturing uses PFCs, HFs and SF<sub>6</sub> as plasma etchers, these emissions are still not well quantified and difficult to link to functional units of computers. GHG emissions presented here include only CO<sub>2</sub> emissions and should thus be seen as minimum values.

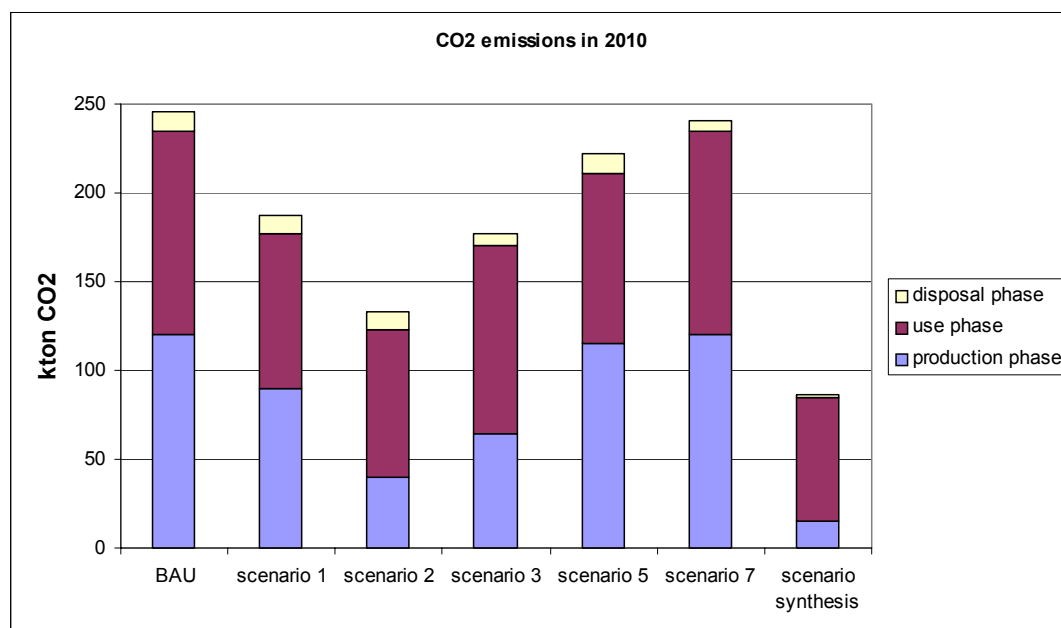


**Figure 1. GHG emissions from computers – 1990 to 2010**

Figure 1 shows that GHG emissions are expected to level-off for the period 2005 – 2010. Indeed, even though computer sales are increasing again, the rapid shift towards LCD screens and laptops should compensate for this.

CO2 emissions come in almost equal proportions from the production phase and the use phase. But only the use phase occurs in Belgium because most of the production phase is abroad. Moreover, only half of the emissions from electricity take place in Belgium, since the other half is due to fuel extraction<sup>1</sup>. Thus, only 25% of the CO2 emissions shown above take place in Belgium.

Figure 2 clearly shows the equal levels of impacts for production and use.



**Figure 2 . CO2 emissions due to consumption of household computers in Belgium– 2010 : impacts per life stage and per strategy**

As can be seen from the figures above, the different strategies could decrease GHG emissions in a very significant way: 64% reduction from the BAU scenario in 2010 for the combination of the different strategies. The main strategies that would be effective are: substituting products i.e. increasing sales

<sup>1</sup> Source : SIMAPRO database, fuel extraction

of LCD screens and laptops (scenario 2), product reuse (scenario 3) and targeting the demand (scenario 1).

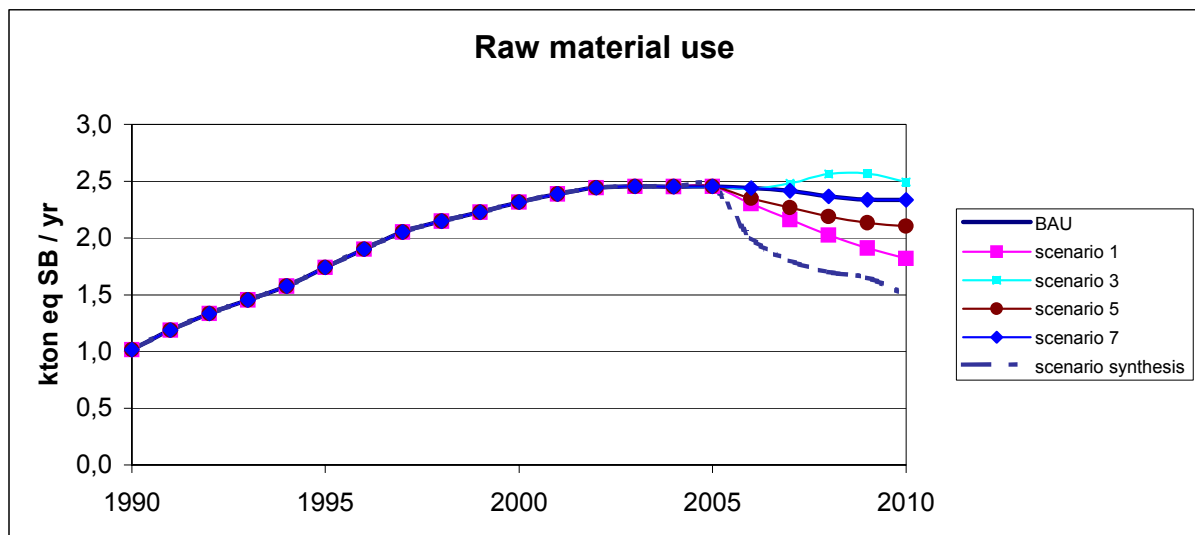
These strategies target different life cycle stages. Increasing the trend towards LCD screens and laptops would thus result in decreased GHG emissions for both the production and the use phase. Indeed, in our model<sup>2</sup>, manufacturing laptops and LCD screens require less material, because they are lighter. This also applies to scenario 1.

In contrast, scenario 3 (reuse) only results in a decrease of GHG emissions in the production phase. These correspond to avoided GHG emissions of new computers that would otherwise have been manufactured.

### Raw materials

Raw materials used by computers come from two main sources: materials used to manufacture the computer; and energy used both to manufacture and to use the computer. Indeed, about 95% of these impacts come from electricity consumption in the use phase. This is due to the electricity mix of Belgium, which uses about 65% of nuclear energy in its electricity production. Although it does not result in high GHG emissions, it still uses a large amount of raw materials due to the extraction of fuels (including uranium).

Therefore, raw material use is expected to level-off until 2010, showing a similar curve as GHG emissions (also linked to energy).



**Figure 3 . Raw material use of computers – 1990 to 2010**

Here the share of the use phase is highly predominant, as is shown in Figure 4, thus encouraging strategies mainly targeting the use phase : scenario 2 (substitution), 1 (targeting the demand) and to a lesser degree scenario 5 (rational use of the product) are the most promising. On the contrary, reusing computers could have an adverse effect on raw material use, since it results in a longer lifespan of old, less effective equipment (mainly due to CRT screens).

<sup>2</sup> However, other studies indicate that this hypothesis could be flawed, laptops being much more complicated to manufacture than desktops [9]

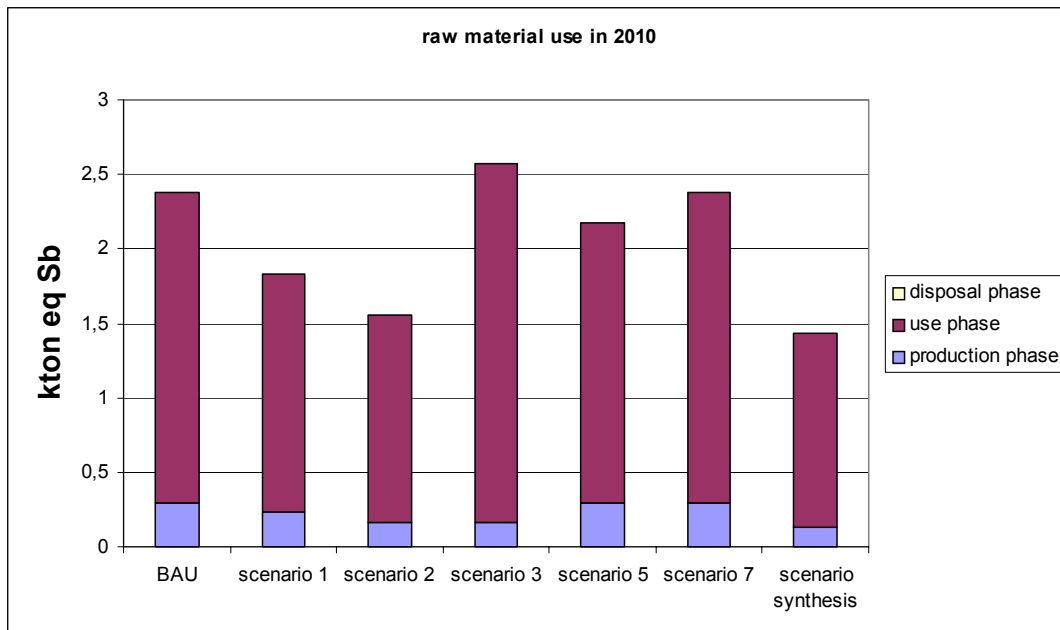


Figure 4 . Raw material use of computers in 2010 per life cycle stage and per strategy

### Waste production

Belgium is a leading country in Europe in terms of product take-back and recycling. Product take-back was installed through the Recupel taxation scheme that started in beginning 2001, thus 2 years before the European WEEE directive<sup>3</sup>.

A computer's average lifespan of 5 years was assumed for the period 1990 - 2005, decreasing to 4 years in 2010. Indeed, most computers are replaced not because they are not working anymore, but because they are obsolete and do not have sufficient capacities to support ever more memory- and speed-demanding applications.

The model used here was a very simple one. The Gaussian distribution of waste production was not taken into account for two reasons: it was difficult to integrate in Excel modelling and, in the case of computers, this Gaussian distribution is not very accurate. Indeed, people tend to store their computer, before either reselling it, or finally dispose of it (usually when it is too old) [10].

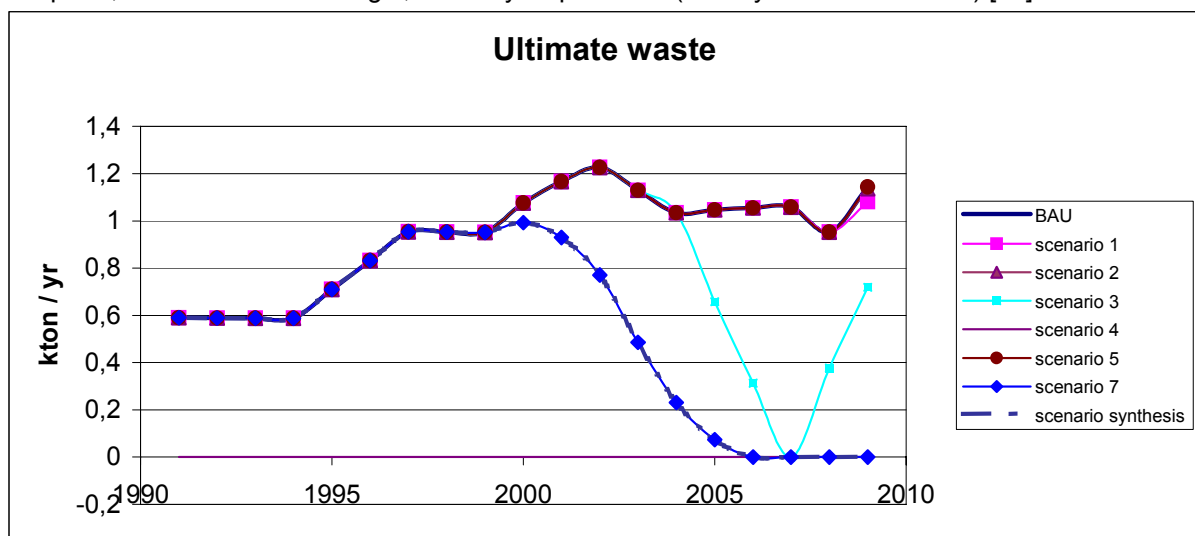


Figure 5 . Waste production of computers : 1990 – 2010

<sup>3</sup> Directive 2002/96/CE.

Figure 5 shows the waste production calculated in this study. It shows that although Belgium is already doing a lot of efforts, waste from computers could be lowered further, especially by improving the recycling processes. It should be noted that these figures do not account for waste production in the production and distribution phases. This is thus an under-estimation of actual impacts of computers over their life cycle, and will be discussed later on.

## **Policies and measures**

The results of this project underlined the importance of impacts in the production phase. Thus, computers should be considered not only as products that consume energy in the use phase (electricity), but also products resulting from very energy-intensive processes that are thus worthy of careful treatment as a “waste”, and where reuse is a policy option that could lead to substantial environmental benefits.

We presented to key stakeholders a list of possible improvement measures taken from literature or foreign experience. The comments from each stakeholder for each strategy are presented hereunder, with a view of showing all opinions on these matters.

### **Scenario 1 : reduction of final demand**

- Industry emphasised the need for a product policy to change consumption patterns, but not consumption levels. The development of services versus computers (e.g., through the increase of computer centres) was not seen as a good option due to possible side-impacts on traffic. However, in order to decrease the “digital gap”, the industry is favourable to the presence of free PC access in town halls.
- For the actors from the social economy (non-profit organisations specialised in the collection and reselling of electrical equipment) (selling second-hand computers), it is important to inform consumers about the impacts of computers when they buy one. Especially, information on the cost of upgrading vs. the cost of a new computer.
- For environmental NGOs, decreasing demand would be possible by subsidizing specialised small and medium enterprises (SMEs) which could bring to households the use of software.
- For consumer organisations, the symbolism of computers is now so important that targeting the final demand would be extremely difficult.
- Researchers in sociology also think that the symbolism of computers is now so important that targeting the final demand would be extremely difficult.

#### Agreements on this strategy

There seems to be an agreement with the difficulty of the task of controlling the demand for computers. Increasing services seems the only possible solution, but a further analysis of the impacts associated with them, as well as the means to promote them, would be necessary.

### **Scenario 2: product substitution**

- Concerning this strategy, the industry underlines the fact that such a substitution must be carried out carefully, taking into account the whole life cycle impacts of the different products as well as a cost / benefit analysis of the change. Attention must also be paid to side-effects of such changes, e.g. concerning the security of the product. Concerning possible measures, ecolabels are not seen as a good measure since it is not a compulsory label, thus disadvantaging other environment friendly products. They also comment that international discussions have already started to develop the Energy Star label.
- For consumer organisations, the promotion of energy efficient computers should preferably take place through compulsory labels rather than ecolabels, because consumers are not receptive to labels. For the same reason, developing existing labels should be preferred to creating new ones.
- For researchers, rather than developing new labels, they prefer field agreements.

#### Agreements on this strategy

There is a general agreement on the uselessness of promoting ecolabels for computers (they are considered to be ineffective labels). Stakeholders agree that a better solution to promote the use of

energy-efficient equipment would be the development of existing compulsory labels, or by field agreements.

### **Scenario 3: product reuse**

- For industry, reuse can be an attractive option if scientific evidence suggests that it is an effective and environmentally friendly solution, and provided that it can be implemented at a reasonable cost, without detracting from the technical characteristics required for the intended application. The limitations with respect to reuse make it very important to continue encouraging research and development (R&D) to improve the eco-efficiency of computers. Industry maintains that the promotion of second-hand computers is not always the best solution, since new PCs are more energy efficient than older ones
- For the actors from the social economy, computers “cost” a lot during their production in terms of environment. Increasing their life span is therefore logical. They are also in favour of open-source software, which enables the consumers to have a flexible system which can evolve as they wish. They also underline that reused computers do not directly compete with new ones on the market; on the contrary, they fulfil different needs (e.g. basic needs in terms of speed and power) in a responsible manner. Finally, they agree with the need to increase the upgradeability of computers, which should be carried out in the assembly phase.
- Consumer organisations warn about a possible rebound effect, where people who cannot afford a new computer could possibly buy a used one, thus increasing the penetration rate of computers in households. Also, the network of second-hand equipment sales should be associated with the new equipment network, so that salesmen can point the consumer towards the best choice depending on needs and constraints. But in this case, second-hand equipment should be interesting to sell for the new equipment distribution network. They also suggest to develop a tool to know the characteristics of the computer fulfilling the consumer’s needs. This tool could be supplied through the internet and sales points.
- For environmental NGOs, in order to lengthen the life span of computers, PC design is very important (for maintenance in particular).

#### Agreements on this strategy

In this strategy there is a clear opposition between the industry and the social economy actors. However, this strategy is particularly important for computers, as about half of their CO<sub>2</sub> emissions occur in the production phase. Further research and market studies would be necessary to determine if second-hand computers compete with new ones on the market place, and if developing them would lead to a rebound effect. It should be emphasised that developing the market for second-hand computers could possibly lead to the creation of new jobs in Belgium.

### **Scenario 5 : improvement of product use**

Many comments from researchers underlined the necessity to help consumers to use computers more efficiently. For example, sociologists believe that stand-by enabling should be set up automatically and less easily changed by users. Also, the benefits for consumers should be clearly stated and given to them, in order to increase the efficiency of communicating.

### **Scenario 7 : material recycling**

- Industry is of the opinion that 1) no measures can be imposed which make the use of recycled material obligatory and 2) market forces themselves must determine where the raw materials yielded via recycling can be most effectively deployed.
- For the social economy actors, this strategy is an “end-of-pipe” measure that is only efficient if accompanied by priority measures linked to prevention and reuse. Experience for white goods shows that monetarisation of flows inhibits reuse and limits the freedom of stakeholders in terms of private initiatives. Moreover, the IT sector works in a business to business view, thus old equipment often find solutions in the framework of leasing contracts or sales with / without take-back of old equipment.
- In general, environmental NGOs insist on the fact that public authorities must orient industrial policy depending on determined social objectives. It should be remembered that economic instruments would be very useful to send the necessary signals to reorient production and

consumption patterns. These instruments are more and more refused by industry delegates. On the contrary, they support awareness measures that have minor impact. Public authorities should overcome these wishes and target public interest.

#### Agreements on this strategy

For this strategy, it is difficult to make conclusions. The industry is against regulations in the field of recycling, and the social economy thinks this should not be a preferred strategy (but rather reuse).

### **Discussion**

#### **Producing computers**

When having a look at the calculations of impacts over the life cycle of computers, we notice that the impacts occurring from the production phase mainly stem from the core process of chip manufacturing. This manufacturing consists in building a series of layers on top of a silicone wafer, therefore laying the network of transistors and diodes that give a chip its functionality. This process requires large amounts of chemicals, water, and energy [8], actually about 500 times the weight of a chip is required in a series of raw materials (including fossil fuels) in order to manufacture it. As a comparison, a car requires twice its weight of fossil fuels to be produced [11].

The GHG emissions estimated by our model is actually an underestimation, since it does not take into account PFCs use as a solvent. In 1993, an estimation of PFC use in the semiconductor industry showed that about as much global warming impact occur due to PFC use as to electricity consumption during the production [8]. PFCs have since been phased out to some extent, but in an un-quantified amount.

Besides waste from end-of-life disposal, waste during production also occurs. In 1997, the Electronics Industry Association of Japan reported 15 kg of waste occurring during the production of a desktop unit [12]. A large majority consists in acid and alkali wastes.

A favoured way of reducing impacts from computer production is to replace part of the production of new computers by the reuse (with possible upgrade) of older ones. This strategy would lead to a decrease of GHG emissions occurring from the production of computers; however, it should be coupled with the replacement of old CRT screens by LCD screens; otherwise, electricity use in the use phase is likely to increase compared to the BAU situation.

This proposition was one of the biggest sources of disagreement in the consultation phase of the study. Industries are reluctant to envisage this strategy that they consider threatening to the economic health of their sector. Open-source software, that can be a good option in order to solve the problem of software equipment on used computers, is also considered with caution. Other actors emphasise the social impacts of reusing computers. One of the main negative effects could be the rebound effect, where used computers would not substitute to new ones but actually increase the penetration rate of computers on the Belgian market. Moreover, given the social status that is linked to owning the latest, most trendy type of computer, this could be hard to achieve.

While reuse thus appears as an approach to be taken cautiously in households, it stills can be a good option in schools and offices, where decisions are taken more rationally than in households.

Concerning the stabilisation of the demand for computers, all stakeholders are doubtful on this possibility. The only way that could possibly work would be to increase the offer of computer as a service, thus developing internet cafés, computer renting etc. How this strategy could be implemented would require a more in-depth analysis of social representations of computers.

#### **Using computers**

The trend of GHG emissions and raw material use is to remain level until 2010. Indeed, although an increase of sales of computers in Belgium can be expected and begins to be noticed, the trend towards more "flat screens" (LCD screens) and laptops is decreasing the average consumption per unit. A CRT screen consumes on the average 60W; a LCD screen, 15 W; a laptop, about 20W [4]. The unknown factor in these figures is the market shares of different screen sizes : indeed, the larger the screen, the higher the electricity consumption. 17" screens seem now the largest category of screens on the market, having largely replaced 15" screens, and even larger screens appear on the market. The trend for the years to come may influence slightly these power consumption figures.

Besides the question of CRT versus LCD screens, the issue of energy efficient equipment should be tackled. Energy efficient equipment can today be identified by either the European Ecolabel, or the Energy Star label. The former is actually not available on the Belgian market; the latter has outdated requirements and does not really identify energy-efficient equipment [13]. Stakeholders are not willing to develop new labels; indeed, there is a general state of confusion on labels in Belgium, consumers generally not recognising them or not knowing what they mean [14]. Creating new labels would only lead to increased confusion. The priority thus seems to update the Energy Star requirements at the international level. This has been undergone at the European level where legislation has been taken for display units (CRT and LCD screens)<sup>4</sup> and criteria are under revision for computers.

Using computers in an efficient manner is also an option. It has small effects on total GHG emissions (electricity being mainly produced from nuclear in Belgium), but higher impacts in terms of raw material use. It requires using the stand-by mode of both the monitor and the central unit, but also shutting down if the equipment is expected to stay unused for a longer period. This would require improving the ergonomics of the stand-by and shut-down management options, which are largely unused by inexperienced users.

### **End-of-life computers**

Belgium is already ahead of existing legislation related to electrical and electronic equipment. This means that additional improvement will be difficult to get. However, several strategies could be beneficial.

First, a “mechanical” decrease of waste production would occur both from the reduction of the demand and from the substitution of products. LCD screens and laptops being much lighter, their development could contribute to waste reduction in terms of quantities.

Second, reusing computers would decrease the production of waste at a significant degree; indeed, if all computers had a second life of the same length as the first one, this would halve yearly waste production from end-of-life products. The feasibility of this option is yet to be assessed, 10 years of working life being considerable for a computer.

Last, increasing recycling targets would enable a further decrease of waste production. This should be envisaged only when reuse is not feasible (not-repairable equipment for instance). However, the network of EEE collection in Belgium (especially for large equipment such as computers) is now well developed; the critical step would therefore be the development of recycling facilities and their treatment capacities.

It should be underlined that this study does not take into consideration a phenomenon that is currently being investigated at the federal level: some computers are exported as second-hand computers to developing countries, but they are actually only EEE waste. Waste treatment in developing countries is of course not as efficient as in Belgium, resulting in very harmful exposure to pollutants for the population [7].

### **Conclusion**

Computers are not often seen as polluting equipment. However, they have non-negligible impacts in terms of GHG emissions, raw material use and waste production. Production in particular is a very polluting phase, and it produces as much greenhouse gas emissions as the CP itself during its whole lifespan; however since it does not occur in Belgium the only possibility to influence this phase is a product-oriented policy aiming at favouring products with the smallest impacts on the environment over their life cycle. A preferred way of doing so is to encourage the reuse of computers; this would require the development of the social economy network, thus also offering the possibility to create jobs. It would also have the benefit of reducing computer waste.

The impacts of the use phase could be mitigated by increasing the proportion of LCD screens and laptops. They could also be addressed by updating the most widely known energy efficiency label to include an active mode power draw component, Energy Star, in order to make it a real commercial incentive for low electricity consumption.

Finally, it is worth underlining the fact that this sector is changing at an increasing pace. Technology developments occur at such a rate that it makes modelling and policy design very difficult. For this

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<sup>4</sup> Commission Decision 2005/42/EC

reason, it is important to involve the industries manufacturing or reselling computers for reuse (social economy network). Belgium is probably not the best country for this to happen, given its small impact on the computer production market, but it is necessary to begin raising awareness and finding solutions at a more global level.

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